University of Alberta

Effects of Strain, Feeding Program, and Photo Stimulation Program on Reproductive Efficiency in Broiler Breeder Females

by

Lea Dawn Muller

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science

in

Animal Science

Department of Agricultural, Food, and Nutritional Science

Edmonton, Alberta

Fall 1997

National Library of Canada
Acquisitions and Bibliographic Services
395 Wellington Street
Ottawa ON K1A 0N4
Canada

Bibliothèque nationale du Canada
Acquisitions et services bibliographiques
395, rue Wellington
Ottawa ON K1A 0N4
Canada

Your file Votre référence

Our file Notre référence

The author has granted a non-exclusive licence allowing the National Library of Canada to reproduce, loan, distribute or sell copies of this thesis in microform, paper or electronic formats.

L'auteur a accordé une licence non exclusive permettant à la Bibliothèque nationale du Canada de reproduire, prêter, distribuer ou vendre des copies de cette thèse sous la forme de microfiche/film, de reproduction sur papier ou sur format électronique.

The author retains ownership of the copyright in this thesis. Neither the thesis nor substantial extracts from it may be printed or otherwise reproduced without the author's permission.

L'auteur conserve la propriété du droit d'auteur qui protège cette thèse. Ni la thèse ni des extraits substantiels de celle-ci ne doivent être imprimés ou autrement reproduits sans son autorisation.

0-612-22642-5

Canada

University of Alberta

Library Release Form

Name of Author: Lea Dawn Muller

Title of Thesis: Effects of Strain, Feeding Program, and Photo Stimulation Program on Reproductive Efficiency in Broiler Breeder Females

Degree: Master of Science

Year this Degree Granted: 1997

Permission is hereby granted to the University of Alberta Library to reproduce single copies of this thesis to lend or sell such copies for private, scholarly, or scientific research purposes only.

The author reserves all other publication and other rights in association with the copyright in the thesis, and except as hereinbefore provided, neither the thesis nor any portion thereof may be printed or otherwise reproduced in any material form whatever without the author's prior written permission.

Lea Muller

77 Carmel Road

Sherwood Park, AB

T8A 5B9

Oct 3, 1997

University of Alberta

Faculty of Graduate Studies and Research

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Effects of Strain, Feeding Program, and Photo stimulation Program on Reproductive Efficiency in Broiler Breeder Females by Lea Dawn Muller in partial fulfilment of the requirements for the degree of Master of Science.

Frank E. Robinson

John J. Feddes

Robert T. Hardin

Lynn McMullen

Frank Novak

Oct. 3, 1997

ABSTRACT

Two experiments were conducted to determine the effect of: 1) light intensity and daylength on sexual maturity, and 2) strain, feeding program, and photostimulation program on carcass traits, ovarian morphology, and reproductive efficiency in female broiler breeders.

In the first experiment, 64 pullets were subjected to one of two light intensities (10 or 100 lux) and to one of two photo schedules (8L:16D or 15L:9D). Birds exposed to long days attained sexual maturity 13 d before those exposed to short days. Long days appeared to increase the incidence of multiple large yellow follicle (LYF) hierarchies. Light intensity had no effect on any trait measured. Some of the traits that were measured included BW, age at sexual maturity, breast wt, liver wt, fatpad wt, ovarian morphology, and carcass composition. Providing 10 lux of light at photo stimulation is adequate for normal sexual development.

In the second experiment, 408 broiler breeder pullets, of two strains, Shaver Starbro (SS) or an Experimental Line (EL) were exposed to one of two feeding programs, Fast Feed (FF) or Slow Feed (SF) and one of two photo stimulation programs, Fast Photoperiod (FP) or Slow Photoperiod (SP), from 20 to 25 wk of age. At photo stimulation, the BW of SS birds was greater than that of EL birds while percentage breast muscle wt was greater in the EL birds than the SS birds. Age at sexual maturity was earlier (5.6 d) in FF birds than SF birds. Breast muscle wt was greater in EL birds (468.2 g) than the SS birds (437.9 g) and breast muscle as a % of BW was also larger in EL birds (17.3 %) versus SS birds (15.8 %). Apart from the lower number of small yellow follicles (SYF; 5-10 mm in diameter) on the EL ovaries, the ovarian morphology of all birds was similar. Prime sequence length was 17.9 d in the EL hens and 14.0 d in SS hens, 14.4 d in FF birds and 17.5 d in SF birds. Settable egg production was not different for the photoperiod or strain main effects, while the SF hens produced 172.9 eggs and the FF hens produced 166.8 eggs. The feeding program exhibited the most differences in this trial, with the SF hens having superior reproductive efficiency.

ACKNOWLEDGEMENTS

First and foremost, I would like to thank the Natural Sciences and Engineering Council of Canada (NSERC), Shaver Poultry Breeding Farms Ltd., Lilydale Co-operatives Ltd., the British Columbia Broiler Hatching Egg Commission, and the Guelph Poultry Industry Centre for their financial support for these experiments. A special thank you goes out to Bob McKay and Mark Newcombe of Shaver Poultry Breeding Farms Ltd. In Cambridge, Ontario for directing me and keeping me busy while fulfilling the internship portion of the NSERC Post Graduate Industrial Scholarship, of which, Shaver was the industry partner. Financial support received through various awards and scholarships -NSERC Post Graduate Industrial Scholarship, the Walter H. John's Graduate Fellowship, and the J Gordin Kaplan Graduate Student Award were very much appreciated.

The staff at the Poultry Research Centre deserve a huge thank-you for all their hard work. When I could not be at the farm I relied on Lyle Bouvier, Nigel Davidson, Giles Hinse, and Shawn Rankin for their knowledge of the projects. I'd like to thank Lyle for his guidance and feed allocation expertise. None of this work could have been completed without the help and dedication of the animal technicians, Felicity Dennis and Brenda Tchir. I'd like to thank Felicity for being my "second mom" and just for being there when I needed to vent some frustrations. My many colleagues-Rob Renema, Paul Goerzen, Kim Thorsteinson, Ruth McGovern, Val Melnychuk, Harry Oosterhoff, Gaylene Fasenko, Travis Turner, Harry Klooster, Jeff Sommer, and Brett Hill have helped out during the past two years and their help is very much appreciated. Martin Zuidhof of Alberta Agriculture was a huge help in the analyzing of the many pages of egg data.

My supervisor, Dr. Frank Robinson deserves a lot of credit. He taught me that there is more to life than vet school. His methods of teaching really opened my eyes to how enjoyable studying can be and to all the opportunities that are available to me. I thank him for instilling in me the love for chickens (and donuts).

I would also like to thank Drs. John Feddes, Bob Hardin, Lynn McMullen, and Frank Novak for serving on my committee. I have always enjoyed statistics, but Dr. Hardin explained statistical concepts so they actually meant something in the grand scheme of things.

My parents, Pat and Al, and my brother, Anthony have always been very supportive of all the decisions I have made in my life. They've helped me through many tough decisions over the past two years.

If anything, they have taught me to do the best I can at everything and to always enjoy what I am doing.

These past two years have gone by so fast, but I have learned a lot and made many new friends. I've learned that it is important to work hard to achieve your goals, but it also equally important to sit back once and awhile and really enjoy all aspects of life.

TABLE OF CONTENTS

CHAPTER			PAGE
1.	**INTRODUCTION**		1
	1.1	**BACKGROUND**	1
		1.1.1 Introduction	1
		1.1.2 Recent Trends	1
	1.2	**REPRODUCTIVE PHYSIOLOGY**	2
		1.2.1 Introduction	2
		1.2.2 The Ovary	2
		1.2.3 The Oviduct and Egg Formation	3
		1.2.4 Light Perception and Its Importance	4
		1.2.5 Feed Restriction and Diet on Sexual Maturity	5
		1.2.6 Fat Content on Sexual Maturity	6
		1.2.7 Body Weight on Sexual Maturity	6
		1.2.8 Production of Abnormal Eggs	7
		1.2.9 Age Effects on Reproduction	9
		1.2.10 Body Weight Effects in Reproduction	10
	1.3	**MANAGEMENT**	11
		1.3.1 Introduction	11
		1.3.2 Strains (Leghorns vs. Broiler Breeders)	11
		1.3.3 Feeding Programs	12
		1.3.4 Lighting Programs	13
		1.3.5 Conclusions	15
	1.4	**INTRODUCTION TO CHAPTERS**	15
	1.5	**REFERENCES**	18

2. **EFFECTS OF INCREASING DAY LENGTH AND LIGHT INTENSITY AT 20 WK OF AGE ON SEXUAL MATURITY IN BROILER BREEDER PULLETS** 22

2.1 INTRODUCTION 22

2.2 MATERIALS AND METHODS 22

2.2.1 Stocks and Management 22

2.2.2 Carcass Examinations 24

2.2.3 Statistical Analysis 25

2.3 RESULTS AND DISCUSSION 25

2.4 REFERENCES 35

3. **EFFECTS OF STRAIN, FEEDING PROGRAM, AND PHOTOSTIMULATION PROGRAM ON CARCASS TRAITS AND OVARIAN MORPHOLOGY AT PHOTOSTIMULATION AND AT SEXUAL MATURITY IN FEMALE BROILER BREEDERS** 37

3.1 INTRODUCTION 37

3.2 MATERIALS AND METHODS 38

3.2.1 Stocks and Management Before 20 wk of Age 38

3.2.2 Stocks and Management After 20 wk of Age 38

3.2.3 Carcass Examinations 39

3.2.4 Statistical Analysis 40

3.3 RESULTS AND DISCUSSION 41

3.3.1 A-Group Birds - Processed at Photostimulation 41

3.3.2 B-Group Birds - Processed at Sexual Maturity 41

3.4 REFERENCES 53

4. **EFFECTS OF STRAIN, FEEDING PROGRAM, AND PHOTOSTIMULATION PROGRAM ON CARCASS TRAITS, OVARIAN MORPHOLOGY, AND REPRODUCTIVE PERFORMANCE AT 60 WK OF AGE** 55

4.1 INTRODUCTION 55

4.2 MATERIALS AND METHODS 56

4.2.1 Stocks and Management 56

4.2.2 Egg Production Records 57

4.2.3 Fertility and Hatchability 57

4.2.4 Bird Processing at 60 wk of Age 58

4.2.5 Statistical Analysis 58

4.3 RESULTS AND DISCUSSION 59

4.3.1 Growth and Sexual Maturity 59

4.3.2 Egg Production 60

4.3.3 Egg Weights 63

4.3.4 Fertility, Hatchability, and Incubation Traits 64

4.3.5 Carcass Traits at 60 wk of Age 65

4.4 REFERENCES 91

5. **GENERAL DISCUSSION AND CONCLUSIONS** 94

5.1 INTRODUCTION 94

5.2 GENERAL DISCUSSION 94

5.3 CONCLUSIONS 98

5.4 REFERENCES 97

LIST OF TABLES

PAGE

TABLE 2-1. Effects of light intensity and photo schedule on age at sexual maturity (SM) (Mean±SEM) 29

TABLE 2-2. Effects of light intensity and photo schedule on BW, shank length, breast wt, and abdominal fat pad wt at sexual maturity (SM) (Mean±SEM) 30

TABLE 2-3. Effects of light intensity and photo schedule on oviduct wt, ovary wt, stroma wt, #SYF, #LYF, and % paired LYF at sexual maturity (SM) (Mean±SEM) 31

TABLE 2-4. Effects of light intensity and photo schedule on carcass composition at sexual maturity (SM) (mean ± SEM) 32

TABLE 2-5. Effects of light intensity and photo schedule on liver wt and liver lipids at sexual maturity (SM) (Mean±SEM) 33

TABLE 2-6. Effects of light intensity and photo schedule on plasma estradiol - 17β concentrations (pg/mL) at 22 wk, 24 wk, and sexual maturity (Mean±SEM) 34

TABLE 3-1. Experimental design indicating the number of birds per treatment group 45

TABLE 3-2. Composition and analyses of experimental diets 46

TABLE 3-3. Effect of strain on BW, shank length, liver wt, breast wt, and abdominal fatpad wt at photostimulation (A-Group birds) (Mean±SEM) 47

TABLE 3-4. Effect of strain on ovary wt and oviduct wt at photostimulation (A-Group birds) (Mean±SEM) 48

TABLE 3-5. Effect of strain on carcass composition at photostimulation (A Group birds) (Mean±SEM) 49

TABLE 3-6. Effects of strain, feeding program and photostimulation program on BW, shank length, liver wt, breast wt, abdominal fatpad wt at sexual maturity (SM) (B-Group birds) (Mean ± SEM) 50

TABLE 3-7. Effects of strain, feeding program and photostimulation program on age at sexual maturity (SM), oviduct wt, ovary wt, stroma wt, #SYF, # LYF, % paired LYF at sexual maturity (B-Group birds) (Mean±SEM) 51

TABLE 3-8. Effects of strain, feeding program, and photostimulation program on carcass composition at sexual maturity (SM) (B-Group birds) (Mean±SEM) 52

TABLE 4-1. Daily feed allowances of feeding program (Fast or Slow) from 21 to 60 wk of age for all birds individually caged (g/bird/d) 68

TABLE 4-2. Effects of strain, feeding program, and photostimulation program on production parameters associated with sexual maturity (C-group birds) (mean±SEM) 69

TABLE 4-3. Effects of strain, feeding program and photostimulation program on parameters associated with egg production to 60 wk of age (C-Group birds) (Mean ± SEM) 70

TABLE 4-4. Effects of strain, feeding program and photostimulation program on number of ovulations, sequence data, and pause data (C-Group birds) (Mean ± SEM) 71

TABLE 4-5. Effects of strain, feeding program and photostimulation program on average weekly egg weights (C-group birds) (Mean ± SEM) 72

TABLE 4-6. Effects of strain, feeding program and photostimulation program on fertility, hatchability, and incubation traits (C-Group birds) (Mean ± SEM) 73

TABLE 4-7. Effects of strain, feeding program and photostimulation program on BW, shank length , liver wt, breast wt, and abdominal fat pad wt at 60 wk of age (C-Group birds) (Mean ± SEM) 74

TABLE 4-8. Effects of strain, feeding program and photostimulation program on oviduct wt, ovary wt, stroma wt, # LYF, and # SYF at 60 wk of age (C-Group birds) (Mean ± SEM) 75

LIST OF FIGURES

PAGE

FIGURE 1-1. Commercial lighting program for broiler breeder pullets (Anonymous, 1993). Light colored portion of bars indicate amount of light per day. 16

FIGURE 1-2. Fast and slow photostimulation programs. Light colored portion of the bars indicate amount of light per day. 17

FIGURE 4-1. Weekly body weights of the C-Group birds for the main effect of strain. 76

FIGURE 4-2. Weekly body weights of the C-Group birds for the main effect of feeding program. 77

FIGURE 4-3. Weekly body weights of the C-Group birds for the main effect of photostimulation program. 78

FIGURE 4-4. Weekly hen day egg production for the main effect of strain. 79

FIGURE 4-5. Weekly hen day egg production for the main effect of feeding program. 80

FIGURE 4-6. Weekly hen day egg production for the main effect of photostimulation program. 81

FIGURE 4-7. Weekly sequence length for the main effect of strain. 82

FIGURE 4-8. Weekly sequence length for the main effect of feeding program. 83

FIGURE 4-9. Weekly sequence length for the main effect of photostimulation program. 84

FIGURE 4-10. Monthly percent fertility for the main effect of strain. 85

FIGURE 4-11. Monthly percent fertility for the main effect of feeding program 86

FIGURE 4-12. Monthly percent fertility for the main effect of photostimulation program 87

FIGURE 4-13. Monthly percent hatchability for the main effect of strain 88

FIGURE 4-14. Monthly percent hatchability for the main effect of feeding program 89

FIGURE 4-15. Monthly percent hatchability for the main effect of photostimulation program 90

1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Introduction

Over the past 40 years, the females which produce chicks for broiler production have changed greatly. Broiler chickens can now achieve a market weight of approximately 1.8 kg in about 41 to 43 days, at a feed conversion close to 1.90 (Singh, 1993). With improvements in the growth rate of in broiler chickens, the ability of meat-type parent stocks to reproduce has been severely reduced. Parents of meat-type poultry must not only have the genetic potential to exhibit fast and efficient growth, but also be capable of reproducing (Robinson *et al*, 1993).

When selecting for fast-growing broiler mothers, one is continually faced with the problem of unsatisfactory production of hatching eggs and the occurrence of a great number of abnormal eggs (van Middelkoop, 1972). The product of parent breeder production is fertile hatching eggs, therefore, it is extremely important both to ensure that the hens are laying at their maximum potential and that the hens are able to store semen so that eggs are fertile. Breeder management protocols are continually being developed and refined to assist in maximizing egg output. Broiler breeders require dedicated programs of feed restriction to maximize egg production and chick production; quantitative feed restriction has become the standard industry procedure.

1.1.2 Recent Trends

As consumer demands and preferences change, so must genetics, in order to meet these demands. The trend today is toward eating healthier. In terms of poultry products, this equates with white meat, specifically the breast muscle. Geneticists are continually faced with the task of developing new and improved strains of chickens, with high breast yield.

Poultry breeding has become one of the most specialized of breeding systems of all livestock species (Van Vleck *et al*, 1987). There are a few large companies which supply the stock for the entire world. Their breeding programs are well- kept secrets which are concerned with viability and resistance to disease. A

commercial crossbreeding system is used to take advantage of females of a breed known for excellence in maternal production characteristics and males are chosen to complement the maternal breed progeny performance. Females are selected for traits such as age at sexual maturity, rate of lay, persistency of lay, egg weight, and shell quality while males are selected for feed conversion efficiency, BW, fertility, and liveability (Al Kulenkamp, Shaver Poultry Breeding Farms Ltd, Cambridge, Ontario, Canada, N1R 5V9, personal communication). The additive genetic improvement from one generation to the next is the mainstay of any breeding program. There are basically four levels to any primary breeding program: pure lines, great grandparents, grandparents, and parents. Broiler chicks are the product of a terminal cross (all crossbred progeny are market animals) of four lines, two from the male and two from the female. Many primary breeders are now leaning toward a cross of five lines to take full advantage of the crossbreeding program (Bob McKay, Shaver Poultry Breeding Farms Ltd, Cambridge, Ontario, Canada, N1R 5V9, personal communication).

1.2 REPRODUCTIVE PHYSIOLOGY

1.2.1 Introduction

Reproduction in female avian species relies on a complex interaction between the hypothalamus, anterior pituitary, and ovary as well as neuroendocrine interrelationships among them. Gonadotropin releasing hormone (GnRH), luteinizing hormone (LH), follicle stimulating hormone (FSH), progesterone, androstenedione, and estradiol are involved in the reproductive process. A good understanding of female reproductive physiology is necessary in order to understand the effects of management on reproductive efficiency.

1.2.2 The Ovary

The right ovary and oviduct are present in embryonic stages of all birds, but the distribution of primordial germ cells to the ovaries of the chicken becomes asymmetrical by day four of incubation, and by day 10, regression of the right oviduct begins (Johnson, 1986).

The ovary of the mature chicken consists of a mass of small ova, of which at least 2000 are visible to

the naked eye (Pearl and Schoppe, 1921). Follicles of the ovary are classified according to their color and diameter. Large yellow follicles (LYF) are large yolky follicles with a diameter greater than 10 mm. Small yellow follicles (SYF) are follicles with a diameter of 5-10 mm, while large white follicles (LWF) have a diameter of 2-5 mm, and small white follicles (SWF) are <1 mm in diameter (Etches, 1993). The avian ovary differs from the mammalian ovary in that there are normally in egg-type hens, four to six preovulatory follicles (LYF) arranged in a distinct hierarchy attached to the ovary via follicular stalks. The LYF are numbered as F1, F2, F3, and so on, denoting size of the follicle in the hierarchy, with F1 as the largest. At sexual maturity, when the hierarchy is established, only the largest follicle (F1) will ovulate, followed on successive days by the second (F2), third (F3) and fourth (F4) largest follicle each of which enlarges to approximately the size of its ovulated predecessor. During ovulation, the F1 ruptures through the stigma, an avascular area of the follicular wall. The ruptured or post-ovulatory follicle (POF) is easily identified for at least 24 h following ovulation and then regresses in the next few days. (Etches, 1993) Once ovulated, the ovum begins its journey through the oviduct, in normal reproductive function.

1.2.3 The Oviduct and Egg Formation

There is one oviduct situated in the left side of the body cavity, but occasionally, a chicken may have two fully developed oviducts. The oviduct consists of five distinguishable regions: infundibulum, magnum, isthmus, shell gland, and vagina.

The ovum is engulfed by the infundibulum within 15 min of ovulation. Within the next 15 min if spermatozoa are present fertilization may occur. Chickens have the ability to store sperm in the sperm storage tubules (SST) for 3 to 4 weeks (Brillard, 1993). The ovum then passes on to the magnum, the longest portion of the oviduct, where it is coated with albumen, which takes on average, 3 h. From the magnum, the ovum goes to the isthmus, the next section of the oviduct. The ovum remains here for about 1.5 h, where the inner and outer shell membranes are formed. Approximately 6 h after ovulation, the egg arrives in the shell gland and remains here for 18 to 20 h. Calcification of the egg occurs in the shell gland where water is imbibed through the membranes into the albumen, a process referred to as "plumping" as it gives the egg its characteristic shape. The vagina is the short section of the reproductive tract connecting the shell gland to the

cloaca. The egg remains in the vagina for a few minutes; this is where the waxy cuticle is secreted on the egg The uterovaginal junction is composed of a series of folds containing the uterovaginal sperm host glands and a muscular sphincter which controls the exit of the completed egg at oviposition. (Etches, 1993)

1.2.4 Light Perception and Its Importance

The response of birds to photoperiod and understanding how photoperiodic signals are perceived by birds and how these signals initiate the events that culminate in egg and sperm production have been a major focus of many studies (Etches, 1996). The physiological control of egg production in the hen involves interaction between circadian rhythm and the physiological systems controlling the rate of follicular maturation (Etches, 1990).

Light is perceived through photoreceptors that transduce the energy contained in photons into a biological signal. In the eye, energy from photons is transduced by photosensitive pigments in the rods and cones, and is transmitted through neurons to the brain where the signal is integrated into an image. The eyes, as well as the pineal gland have received much attention for their possible roles in reproduction in birds. In an experiment by Siopes and Underwood (1987), the influence of the pineal gland and the eyes on reproductive performance in turkeys was examined. The treatments consisted of some hens undergoing pinealectomy, while others underwent bilateral ocular enucleation, or both, while held on 8 hours of light (8L:16D) and were photostimulated to 16 hours of light (16L:8D). Pinealectomy significantly delayed the onset of egg production suggesting a progonadal function for the pineal gland in the sexually developing turkey hen. The rate of photo-induced sexual development was not significantly altered by bilateral ocular enucleation. This implies that the eyes play no role in mediating photostimulated sexual development in birds. Pinealectomy has no (or short-lived) effect on photo-induced gonadal development in a variety of species including sparrows, quail, chickens, and ducks; this is not so in turkeys. It seems possible that the pineal gland and the eyes of at least some birds are integral components of the neuroendocrine apparatus mediating the effects of photoperiod on reproduction (Siopes and Underwood, 1987).

Through extensive studies, it has been demonstrated the photoreceptors in the hypothalamus are the biological transducers that convert photon energy into neural impulses. These neural impulses are then

amplified by the endocrine system to control ovarian and testicular function and, consequently, the multitude of reproductive functions, behaviors, and secondary sexual characteristics (Etches, 1996).

1.2.5 Feed Restriction and Diet on Sexual Maturity

Considerable research has been conducted to define the requirements for the onset of sexual maturity in female broiler breeders. Modern broiler strains have the ability to grow quickly and therefore consume more food without parallel improvement in their ability to convert food into lean tissue, and they mature younger than previously (Bornstein *et al*, 1984). This suggests that broiler breeder females are reaching sexual maturity at a younger age, but a higher BW than before that age. There are hypotheses that a minimal BW (Bornstein *et al*, 1984; Soller *et al*, 1984), a minimum body fat pool (Bornstein *et al*, 1984), feed restriction (Pym and Dillon, 1974; Robinson *et al*, 1993; Wilson *et al*, 1995), and age may act individually or in combination with one another to influence the onset of sexual maturity.

Both the level of feeding as well as diet can have great effects on birds in terms of sexual maturity. There is a strong negative relationship between BW and reproductive efficiency in domestic poultry. Quantitative feed restriction has become the industry standard practice in order to overcome this problem. There is a considerable diversity of opinion as to the optimum level of feed restriction or the optimum timing and duration of feed restriction. The viewpoint 20 years ago was that feeding *ad libitum* during the entire laying period may be wasteful and it may be that restriction should be continued into the laying period (Pym and Dillon, 1974). In general, groups restricted during rearing and then fed *ad libitum* during laying were the most profitable. The age at which pullets are allowed free access to food may greatly affect their subsequent performance. If *ad libitum* feeding is offered too soon, much of this food will be directed to increasing the weight of body components not associated with production whereas if they are restricted too late, the delay in maturity may be so great that it is virtually impossible to compensate in production (Pym and Dillon, 1974).

Yu *et al* (1992a) observed the effects of feed allowance during rearing and breeding in female broiler breeders. Birds that are FF (full-fed during rearing and prebreeding) and birds that are FR (full-fed during rearing and restricted during prebreeding) arrived at sexual maturity at approximately the same age irrespective of feed intake and changes in body composition during the prebreeding period. The same was

observed for RF (restricted during rearing and full-fed during prebreeding) and RR (restricted during rearing and prebreeding). These results suggest that feed intake and growth during the rearing period rather than feed intake and changes in body composition during the prebreeding period is more important in determining age at sexual maturity in female broiler breeders as it get them to a weight above the threshold

In an experiment by Soller *et al* (1984), the effects of feed restriction and diet on the onset of sexual maturity on white Rock broiler breeders was studied. In the restriction experiment, birds were subjected to moderate, severe, or very severe feed restriction and then allowed to gain weight until first egg, while in the diet experiment, birds were severely restricted during rearing but were then allowed to gain weight on one of two metabolizable energy/protein (ME/P) ratio diets until first egg. Very severe restriction throughout rearing resulted in a significant increase in carcass weight at first egg when birds were gradually released from feed restriction. This increase in carcass weight was primarily due to an increase in body fat content.

1.2.6 *Fat Content on Sexual Maturity*

A minimum body fat composition may be a critical factor for determining the onset of sexual maturity. This is based on observations that menstrual cycles in human females cease when body fat reserves are depleted by anorexia nervosa or exercise and resume when fat stores are replenished (Frisch and Revelle, 1970). In its strong form, the body fat hypothesis stated that attainment of a given body fat composition alone is sufficient to trigger the onset of sexual maturity. In the experiment by Soller *et al* (1984), this hypothesis would mean that the very severely restricted birds or birds on high ME/P would have reached this fat level earlier than the other groups of birds, and hence attained sexual maturity sooner, but this did not occur. Consequently, the higher fat content birds entered sexual maturity at a later age and a higher BW. This suggests that body fat content of fat percentage alone is not sufficient to initiate sexual maturity, but rather, there is a possible minimum lean body mass requirement.

1.2.7 *Body Weight on Sexual Maturity*

A minimum BW requirement has been proposed as an explanation for the observed direct relationship between the degree of food restriction of pullets during the rearing period and the subsequent

delay of sexual maturity. This delay could be controlled by allowing BW to increase sharply at the end of the rearing period. The minimum weight for onset of sexual maturity is also important in that it sets a lower limit to the degree of food restriction that can be implemented in broiler breeder flocks. (Soller *et al*, 1984)

Under nutrition of female vertebrates delays sexual maturity until about the same weight is attained as that of a comparable group of well-fed animals at sexual maturity (Soller *et al*, 1984). This phenomenon and others have led to the view that the attainment of some minimum BW is required for the onset of sexual maturity. Brody *et al* (1980) found that a minimum BW of 2300 to 2700 g is required for the onset of sexual maturity, but birds fed *ad libitum* generally reach and pass this weight at 14 to 15 wk but do not come into lay until 21 to 25 wk. This raises the possibility of a minimum age for the onset of sexual maturity.

Once a minimum age has been reached the attainment of a BW in the critical range is essential for the onset of lay, which is consistent with the common observation that the more severe the food restriction, the longer the delay of the start of lay. Under nutrition may produce a distortion of the normal growth pattern, with some parts of the body having priority of growth over others, and with some functions appearing only after the attainment of a certain size (Bornstein *et al*, 1984).

Each primary breeder has its own parent management guide outlining suggested rations and feeding programs. This shows that there is a perceived strain difference between each breeder which must be addressed. The optimal degree of feed restriction is difficult to define due to these strain differences and continual changes in the genetic composition of stocks by primary breeders (Robinson *et al*, 1993). Similarly, there appears to be a downward shift in the typical BW curves for the primary breeders, thereby resulting in the attainment of a slightly lower BW at the onset of sexual maturity. These management guides provide the best estimate of ideal BW targets for birds from hatch to the end of lay, however, there is a considerable range between upper and lower limits of targets (Wilson *et al*, 1995).

1.2.8 Production of Abnormal Eggs

The mothers of broiler chicks not only lay fewer eggs than layers but also a higher percentage of abnormal eggs. These abnormal eggs may fall into any of the following categories:

a) double-yolked

b) membranous (or shell-less) of normal shape

c) soft-shelled of normal shape

d) membranous eggs with a flattened area

e) soft-shelled eggs with a flattened area

f) shell eggs with a bulge

g) soft-shelled eggs with a bulge

h) normal-shaped eggs with yolk material on the outside

(van Middelkoop, 1971). Double-yolked eggs are the most common abnormal eggs. Some eggs are laid prematurely resulting in inadequate shells (soft-shelled or shell-less). One explanation for the incidence of soft-shelled or shell-less eggs pertains to the role that prostaglandins play in oviposition. Prostaglandins (PG) are synthesized in the uterus, vagina and ovary of the chicken's reproductive tract. Prostaglandins are involved in the spontaneous oviposition of chicken eggs; contractions of the shell gland are stimulated by PG. The premature expulsion of soft-shelled or shell-less eggs may be a result of premature release or overproduction of PG, which in turn causes the uterus (shell-gland) to contract (Hester *et al*, 1991). Consequently, not all soft-shelled eggs are laid prematurely.

Some hens will consistently lay eggs prematurely, and others will produce normal hard-shelled eggs on some days and then lay soft-shelled or shell-less eggs on other days. A term used to describe this phenomenon is EODES (erratic oviposition and defective egg syndrome). EODES-afflicted hens lay a high incidence of multiple-yolked eggs and frequently lay more than one egg per day. Jaap and Muir (1968) found that lower egg production of broiler strains appears to differ from low egg production in non-broiler strains by these erratic ovipositions. Such hens lay in an erratic nature throughout the day and night.

The most frequently occurring forms of abnormal eggs from healthy hens are mainly due to one and the same cause, ie. too short an interval time between two succeeding ovulations. It is observed that hens which often lay two eggs in a day show this regularly and it usually appears at the beginning of a sequence (van Middelkoop, 1971). The abnormality of the first egg is not as evident as the second. Normally, the first egg is held in the shell gland past its normal time of oviposition. The next egg arrives at the shell gland and

presses against the retained egg. The first of a pair of eggs has a hard shell with additional rough shell calcification, usually in the form of a longitudinal band. The second egg is often more or less soft-shelled. It usually has a flattened area which is thinner than the rest of the shell and surrounded by a band of wrinkled shell. The flattened area is closer to the pointed than the blunt end. The second egg occasionally has both a compressed sided shell as well as symptoms of a body-checked egg. The origin of the body checked eggs can be explained by the bumping against of each other of two eggs in the shell gland. The cracks can then be sealed by the secretion of calciferous material, since the shell formation is still in progress. When the first egg in the shell gland is still membranous when the second egg reaches it, this may result in two eggs with a characteristic bulge. Both eggs are still small, membranous and unplumped, therefore the eggs can still grow by plumping while in the shell gland. Since there is no shell deposited on the points of contact between these eggs, the shell membranes continue to stretch as more moisture is taken in by the egg. As a result of the stretching membranes, a bulge is formed. (van Middelkoop, 1971).

1.2.9 Age Effects on Reproduction

There is also an age effect that must be considered in determining the cause of abnormal eggs. There appears to be a higher incidence of soft-shelled and shell-less eggs at the beginning of the laying cycle as well as at the end. When hens are young, the positive and negative feedbacks of hormones between the hypothalamus and the ovary may not yet be properly established resulting in a dysfunction of oviposition. Late in lay, eggs tend to be larger, thus shell quality is poor as there may be inadequate calcium in the diet or the bird is simply not as efficient at calcium uptake from the diet or bones to ensure the entire egg is covered with shell. As the hen ages, she produces fewer but larger eggs. With age, yellow yolk is deposited in fewer follicles which are larger in size (Bahr and Palmer, 1989). The interval between ovulations increases from 24-25 to 26-27 h or more, as the hen ages. The result is a shorter sequence and a decrease in egg production (Bahr and Palmer, 1989).

Age also has effects on fertility and the duration thereof. As a bird ages, BW increases. This increase in BW is most likely due to an increase in fat. An accumulation of fat occurring at the uterovaginal junction may reduce spermatozoal storage capacity thereby decreasing the duration of fertility (McDaniel *et*

al, 1981). The time that spermatozoa are to be stored decreases with age, not because of lack of storage capacity in the SST, but due to the increased rate of release of spermatozoa in older birds (Brillard, 1993) Due to the decrease of sperm retention time in older birds, it is expected that the duration of fertility will decrease in relation to increasing age of the hen. This decrease in sperm retention could also be due to a reduction in muscle tone in older birds thereby resulting in more sperm released close to the time of insemination.

1.2.10 Body Weight Effects on Reproduction

In order to determine the effects of BW on reproductive efficiency in broiler breeders, it is common practice to compare full-fed birds to feed-restricted birds. There is an evident negative relationship between BW and reproductive efficiency.

Reproductive inefficiency is evident in reduced egg production and shell quality, in addition to an increased incidence of multiple-yolked eggs, obesity-related mortality, infertility, and embryonic loss (Robinson and Wilson, 1996). Fertility is negatively affected in broiler breeder hens that are excessively above target BW (Yu *et al*, 1992b). Full-fed hens generally produce fewer total and settable eggs and have lower percentages of egg fertility, hatchability, and embryonic viability. Differences in BW in broiler breeders are predominantly due to differences in fat, therefore accumulation of fat in the uterovaginal junction may reduce the duration of fertility by reducing storage of the sperm storage glands. Goerzen *et al* (1996), concluded that extreme differences in BW are required in order to affect duration of fertility. To reduce these problems, broiler breeders are commonly managed under a quantitative feed-restriction program. Although this may help to alleviate some reproductive problems, it does delay sexual maturity. A full-fed broiler breeder will come into production sooner than a restricted bird, but it will also lay fewer eggs.

A full-fed broiler breeder hen may have problems that are related to ovarian morphology. Full-fed broiler breeders have more large yellow follicles than do restricted hens; this larger number can result in an ovary with a double or even triple hierarchy of follicles. Full-fed broiler breeder hens have an average of 12 large yellow follicles at sexual maturity (Hocking *et al.*, 1987; Yu *et al.*, 1992b) while approximately 7 large yellow follicles are observed on the ovary when birds are feed restricted. Along with multiple hierarchies,

comes the possibility of multiple-yolked eggs. So, more follicles does not necessarily mean more eggs. In some cases, a reduction in egg production in broiler breeder hens can be attributed to atresia or more likely, regression. Atresia normally involves the shrinking of individual large yellow follicles on the ovary, whereas regression involves the ovary as a whole. Atresia in large yellow follicles is rare for birds at peak production performance, unless some adverse stimulus causes cessation of egg laying (Gilbert *et al*, 1983).

1.3 MANAGEMENT

1.3.1 Introduction

Breeder management protocols are continually being developed and refined to assist in maximizing egg output in broiler breeders and maximizing growth in broiler chickens. It appears that birds are being pushed to the limit. Photostimulation programs are being implemented earlier and earlier resulting in a pullet reaching sexual maturity at an earlier age and smaller BW. There are also vast differences between egg-type (leghorns) and meat-type (broiler breeders) birds in terms of what is expected of them.

1.3.2 Strains (Leghorns vs Broiler Breeders)

"We want broiler breeders to think and act like leghorns but we want their offspring to show that they are broilers" (Robinson and Wilson, 1996). There are marked differences between egg-type strains (Single Comb White Leghorns) and meat-type strains (Broiler Breeders) in terms of ovarian morphology and total egg production. Single Comb White Leghorn hens are considered reproductively superior to broiler breeder hens. Compared with egg-type hens, broiler breeders lay approximately half as many eggs (Hocking *et al*, 1987, 1989). This difference in egg production is partly due to the follicular hierarchy of the ovary. *Ad libitum* fed leghorns normally have an ovary containing a single hierarchy of 7 to 8 LYF whereas full-fed broiler breeders hens may have up to 12 or more LYF at sexual maturity (Yu *et al*, 1992b), more is not necessarily better in terms of ovarian LYF numbers. Too many large follicles are associated with double hierarchies and multiple ovulations (Hocking *et al*, 1987). The mothers of broiler chicks not only lay fewer eggs than layers but also lay a higher percentage of abnormal eggs (van Middelkoop, 1971). This higher number of abnormal eggs is greatly a result of double hierarchies often preset in broiler breeders.

Occurrences such as multiple ovulations, soft-shelled and shelless eggs, follicular atresia, and internal ovulation and laying are observed more frequently in meat-type stocks than egg-type stocks, but can be reduced if a feed restriction program is implemented.

1.3.3 Feeding Programs

Much work has been done to evaluate the effects of *ad libitum* versus restricted feeding on growth and reproductive characteristics. There is a well-documented negative relationship between BW and reproductive efficiency in poultry, which limits the ability of meat-type stocks to reproduce. Most commercial broiler breeders are feed restricted during rearing and breeding to limit BW (Summers and Leeson, 1985). Such restriction programs can reduce BW and mortality, improve feed efficiency, and improve egg fertility and shell quality, and production (Pym and Dillon, 1974). The degree of restriction has a profound effect on reproductive efficiency. It is now standard practice to limit feed intake of broiler breeder chickens during both the rearing and laying periods (Robinson *et al*, 1991). Hens when fed *ad libitum* during the prebreeding and breeding periods may put energy and nutrient intake into growth and fat storage instead of using it for reproductive performance (Yu *et al*, 1992a). *Ad libitum* feeding results in an increase in ovarian follicles which does not correlate to an increase in egg production. "More is not better". Multiple ovulations, abnormal eggs (soft-shelled and shelless), atresia, and internal ovulation and laying may be a result of *ad libitum* feeding. Restricted feeding reduces the number of large follicles which aids in reducing the above anomalies, but it is not without its drawbacks. Sexual maturity is delayed as a result of feed restriction.

Accurate and complete records on bird numbers, BW, and uniformity are essential for a feed control program. It is necessary to regularly weigh samples of birds during the rearing and growing periods and to compare actual BW with primary breeder recommended target weights in order to control growth rate. A standard parent stock feeding program would consist of *ad libitum* feeding for the first week or two. This would be followed by some sort of feed restriction such as skip-a-day feeding, daily feed restriction, etc. Feed restriction is continued into the breeding period, but now egg production as well as BW must be considered in allocating feed (Anonymous, 1993).

"Slow feed" and "fast feed" are quickly becoming common industry phrases in terms of feed restriction programs for broiler breeders (Robinson *et al*, 1995). The difference between the two is basically the rate of weekly feed allocation increases. Slow feeding is a very conservative program relying on moderate increases in feed whereas fast feeding is a more aggressive approach of generous feed increases.

1.3.4 Lighting Programs

The poultry industry relies heavily on artificial daylight to maximize performance. Such light can be described as photoperiod, intensity, and wavelength and spectral characteristics (Denbow *et al*, 1990). The importance of increasing daylength is evident in planning commercial lighting regimes. Light has a stimulatory effect on the pituitary gland. Both duration of light and light intensity appear to be important in this stimulatory effect.

Birds display different responses to differing (increasing or decreasing) daylengths. Terms of importance in cases like these are critical daylength, marginal daylength, and saturation daylength. Critical daylength is the minimum daylength required to stimulate LH secretion, and hence ovulation. For most species of birds, if there is less than 11 to 12 hours of daylight, sexual maturity will not be reached, or it will be reached at an old age. Marginal daylength is defined in terms of critical daylength. Over a certain range of daylengths, above critical daylength, there is a direct relationship between daylength and plasma LH concentrations (Sharp, 1984). In simpler terms, as daylength is increased above that of the critical daylength (up to about 14 h), an increase in plasma LH concentrations is still observed. As daylength is increased further, a saturation daylength is reached which stimulates the maximum release of LH. At this daylength, the photoperiodic response is said to be "saturated" and further increases in daylength have no effect on LH secretion. (Sharp, 1984)

When initiating lighting programs, the above terms must be kept in mind. Periods of light and dark are usually combined in one of three ways for application in either commercial or experimental situations. A conventional lighting regime consisting of a single photophase (light period) and scotophase (dark period) that total 24 h, is the most common. Alternatively, skeleton or intermittent lighting regimes contain more than one photophase and scotophase that recur at 24 h intervals. Ahemeral lighting regimes contain recurring

periods of light and dark that, in combination, may be shorter or longer, but not equal to 24 h in length (Etches, 1990). Figure 1.1 displays a conventional lighting program.

Not until recently have the terms "fast photoperiod" and "slow photoperiod" been used (Robinson *et al*, 1995). A fast photoperiod consists of an abrupt change in the amount of light birds are exposed to from 8L:16D during rearing to 15L:9D in a single step. A slow photoperiod is comprised of gradual weekly increases of light (see Fig 1.2).

There is little data published on the effects of light intensity at sexual maturity on ovarian morphology, however, there have been numerous studies on the minimum light intensity required to elicit a photoperiodic response. The perception of light and hence the attainment of sexual maturity, is dependent on light intensity. More likely, recognizing the difference in light intensity between "lights on" and "lights off" is important (Etches, 1996). Morris and Bhatti (1978) concluded that light intensity of the photoperiod must be 10 fold greater than the intensity of the scotoperiod in order for birds to respond to photoschedule. Siopes (1991) concluded that there appears to be a wide range of intensity levels to which reproductive functions of turkeys respond similarly. Also, it appears that once a certain level of light intensity is achieved, sufficient light reaches the photoperiodic apparatus to maximally stimulate reproductive function. Light intensity is commonly used to control cannibalism in laying houses, but a reduction in light intensity can result in a loss of a dozen eggs or more per bird a year (Morris, 1967).

Long day lengths have two distinguishable, opposite effects on the reproductive system in species that become absolutely refractory. They initially stimulate a rapid and complete "switch on" of all components but this is inevitably followed by an equally complete "switch off" in a totally refractory state (Nicholls *et al.*, 1988). Photo-refractoriness is the common term given to this apparent switching off. With the passage of time, the transduction of photon energy into a neural signal begins to fail and eventually, the bird cannot maintain maximal levels of gonadotropin secretion (Etches, 1996). Occasionally gonadotropin secretion is reduced to a level that is insufficient to maintain the gonad and the ovary regresses. Hens that are photo refractory cannot be photostimulated again until they have been exposed to short days for 10 to 12 weeks (Etches, 1996). Force molting programs are often implemented to overcome photo refractoriness

1.3.5 Conclusions

This chapter outlines the criteria necessary for reproductive efficiency in broiler breeder hens. It is clear that there are a number of different management programs which must be considered. As consumer demands change, so must the genetic make-up of commercial chickens. As genetics change, so must management programs. In order to evaluate the changes in genetics and management, it is essential to carry out scientific research.

1.4 INTRODUCTION TO CHAPTERS

As consumer and industry demands are continually changing, genetic improvements are necessary. Fine-tuning genetics includes improvements in egg production in parent stocks and faster growth in progeny. Two experiments were conducted to determine the effects of genetics and management practices. The importance of daylength on sexual maturity in poultry is well understood and documented, but there is little published on the effects of light intensity on ovarian morphology at sexual maturity. Chapter 2 focusses on the effects of increasing daylength alone and in combination with different light intensities on sexual maturity in broiler breeder pullets. Chapters 3 and 4 comprise the majority of the research focussing on the effects of genetic strain, feeding program, and photostimulation program on reproductive efficiency in broiler breeder hens.

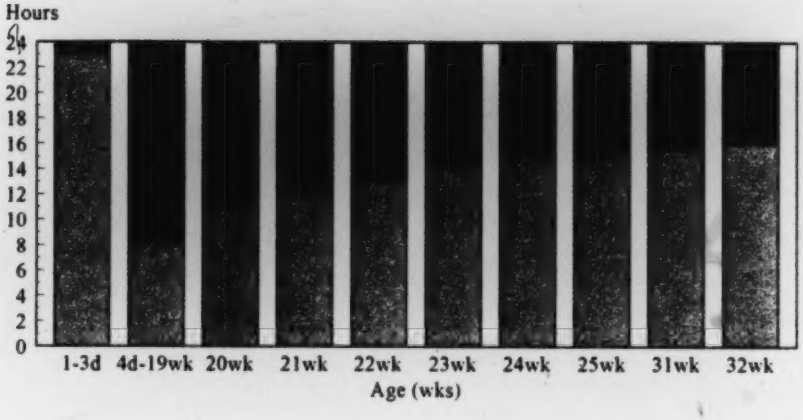

FIGURE 1-1. Commercial lighting program for broiler breeder pullets (Anonymous, 1993). Light colored portion of bars indicate amount of light per day.

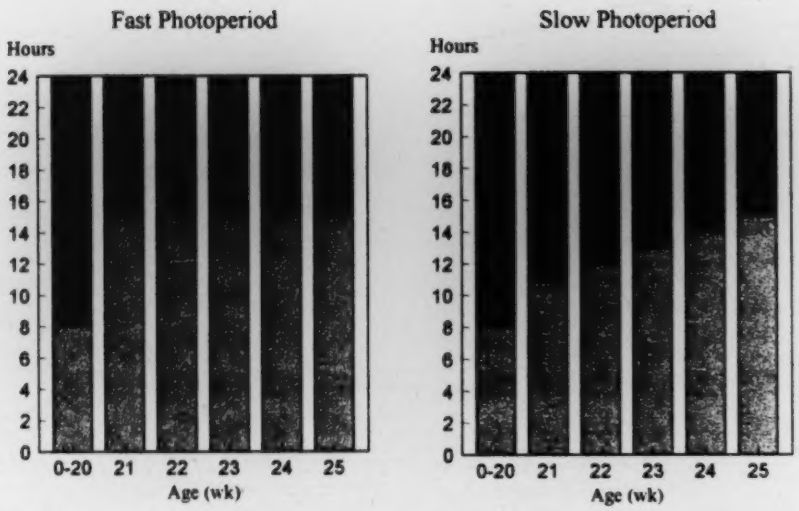

Figure 1-2. Fast and slow photostimulation programs. Light colored portion of the bars indicate amount of light per day.

1.5 REFERENCES

Anonymous. 1993. Shaver Starbro Parent Management Guide (T-03-M), Shaver Poultry Breeding Farms Limited, Cambridge, ON, Canada, N1R 5V9

Bahr, J.M. and Palmer, S.S. 1989. The influence of aging on ovarian function. Crit. Rev. Poult. Biol. **2**:103-110.

Bornstein, S., Plavnik, I., and Lev, Y. 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci. **25**: 323-341.

Brillard, J. P., 1993. Sperm storage and transport following natural mating and artificial insemination Poult. Sci. **72**:923-928.

Brody, T., Eitan, Y., Soller, M., Nir, I., And Nitsan, Z. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sci. **21**: 437-446.

Denbow, D.M., Leighton, A.T., and Hulet, R.M. 1990. Effect of light sources and light intensity on growth performance and behavior of female turkeys. Br. Poult. Sci. **31**: 439-443.

Etches, R.J. 1990. The Ovulatory cycle of the hen. CRC Crit. Rev. Poult. Biol. **2**: 293-318.

Etches, R.J. 1993. Reproduction in Poultry. *In*: G.J. King (Editor), Reproduction in Domesticated Animals. Pages 495, 500-503.

Etches, R.J. 1996. Reproduction in Poultry. CAB International, Wallingford UK.

Frisch, R.E. and Revelle, R. 1970. Height and weight at menarche and a hypothesis of critical body weights and adolescent events. Science, New York **169:** 397-399.

Gilbert, A.B., Perry, M.M., Waddington, D., and Hardie, M.A. 1983. Role of atresia in establishing the follicular hierarchy in the ovary of the domestic hen (*Gallus domesticus*). J. Repro. Fertil. **69**: 221-227.

Goerzen, P.R. , Julsrud, W.L., and Robinson, F.E. 1996. Duration of fertility in *ad libitum* and feed-restricted caged broiler breeders. Poult. Sci. **75**: 962-965.

Hester, P.Y., Newton, N.F., and Klingensmith, P.M. 1991. Plasma, follicular, and uterine levels of prostaglandins in chickens laying soft-shelled and shell-less eggs. Poult. Sci. **70**: 1585-1593.

Hocking, P.M., Gilbert, A.B., Walker, M., and Waddington, D. 1987. Ovarian follicular structure of White Leghorn fed *ad libitum* and Dwarf and normal broiler breeders fed *ad libitum* or restricted to point of lay. Br. Poult. Sci. **28**: 493-506.

Hocking. P.M., Waddington, D., Walker, M.A., and Gilbert, A.B. 1989. Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. Br. Poult. Sci. **28:** 495-506.

Jaap, R.G. and Muir, F.V. 1968. Erratic oviposition and egg defects in broiler-type pullets. Poult. Sci. **47**: 417-423.

Johnson, A.L. 1986. Reproduction in the female. Pages 432-451 *in*: Avian Physiology. P.D. Sturkie, ed. Springer-Verlag, New York.

McDaniel, G. R., J. Brake, and M. K. Eckman, 1981. Factors affecting broiler breeder performance. 4. The interrelationship of some reproductive traits. Poult. Sci. **60**:1792-1797.

Morris, T.R. 1967. The effect of light intensity on growing and laying pullets. World's Poult. Sci. J. **23**: 246-252.

Morris, T.R. and Bhatti, B.M. 1978. Entrainment of oviposition in the fowl using bright and dim light cycles. Br. Poult. Sci. **19**: 341-348.

Nicholls, T.J., Goldsmith, A.R., and Dawson, A. 1988. Photo refractoriness in birds and comparison with mammals. Physiological Reviews **68**: 133-176.

Pearl, R. and Schoppe, W.F. 1921. Studies on the physiology of reproduction in domestic fowl. XVIII. Further observations on the anatomical basis of fecundity. J. Exp. Zool. **34**: 101-118.

Pym, R.A.E. and Dillon, J.F. 1974. Restricted food intake and reproductive performance of broiler breeder pullets. Br. Poult. Sci. **15**: 245-259.

Robinson, F.E. and Wilson, J.L. 1996. Reproductive failure in overweight male and female broiler breeders. Animal Feed Science Technology **58**: 143-150.

Robinson, F.E., Robinson, N.A., and Scott, T.A. 1991. Reproductive performance, growth rate, and body composition of full-fed versus feed restricted broiler breeder hens. Can. J. Anim. Sci. **71**: 549-556.

Robinson, F.E., Wilson, J.L., Yu, M.W., Fasenko, G.M., and Hardin, R.T. 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. **72**: 912-922.

Robinson, F.E., Lupicki, M.E., Wautier, T.A., Robinson, N.A., Hardin, R.T., and Wilson, J.L. 1995. Feed and photoperiod management of broiler breeder hens: limiting ovarian development to maximize chick production. Pages 196-205 *in*: Proceedings of the 16th Western Nutrition Conference. September 13/14, 1995, Saskatoon, Saskatchewan.

Sharp, P.J. 1984. Season breeding and sexual maturation in: Reproductive Biology of Poultry. Br. Poult. Sci. Ltd. Alden Press Ltd: Oxford. Pages 203-211.

Singh, N. 1993. The Poultry Industry. *In*: J. Martin, R.J. Hudson, and B.A. Young (editors), Animal Production in Canada. University of Alberta: Edmonton, Alberta. Pages 117-140.

Siopes, T.D. 1991. Light intensity effects on reproductive performance of turkey breeder hens. Poult. Sci. **70**: 2049-2054.

Siopes, T.D. and Underwood, H.A. 1987. Pineal gland and ocular influences on turkey breeder hens. I. Reproductive performance. Poult. Sci. **66**:521-527.

Soller, M., Eitan, Y., and Brody, L. 1984. Effect of diet and early quantitative feed restriction on the minimum weight requirement for onset of sexual maturity in White Rock broiler breeders. Poult. Sci. **63**: 1255-1261.

Summers. J.D. and Leeson, S. 1985. Poultry Nutrition Handbook. University of Guelph, Guelph, ON, Canada.

Van Middelkoop, J.H. 1971. Shell abnormalities due to the presence of two eggs in the shell gland. Archiv fur Geflugelkunde **35**: 122-127.

Van Middelkoop, J.H. 1972. The relationship between ovulation interval of White Plymouth Rock pullets and the laying of abnormal eggs. Archiv fur Geflugelkunde **36**: 223-230.

Van Vleck, L.D., Pollak, E.J., and Oltenau, E.A.B. 1987. Genetics for the Animal Sciences. W. H. Freeman and Company, New York. Pages 359, 378.

Wilson, J.L., Robinson, F.E., Robinson, N.A., and Hardin, R.T. 1995. Effects of feed allocation on female broiler breeders. J. Appl. Poult. Sci. **4**:193-202.

Yu, M.W., Robinson, F.E., and Robblee, A.R. 1992a. Effect of feed allowance during rearing and breeding on female broiler breeders. 1. Growth and carcass characteristics. Poult. Sci. **71**:1739-1749.

Yu, M.W., Robinson, F.E., Charles, R.G. and Weingardt, R. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders. 2. Ovarian morphology and production. Poult. Sci. **71**. 1750-1761.

2. EFFECTS OF INCREASING DAY LENGTH AND LIGHT INTENSITY AT 20 WK OF AGE ON SEXUAL MATURATION IN BROILER BREEDER PULLETS

2.1 INTRODUCTION

The transition from pullet to hen is important in broiler breeder management as the development of the brain-ovarian axis is being established at this time. Prior to photo stimulation, an organized communication network of positive and negative hormonal feedbacks does not exist in the pullet, and hence, the ovary does not develop. Transfer of hens from a short day (eg. 8 hours of light, 16 hours of dark; 8L:16D) to a long day (eg. 15L:9D) provides the photoperiodic signal that initiates gonadotropin secretion, growth of reproductive organs and, consequently, egg production (Etches, 1996). The importance of increasing day length on sexual maturity in birds is evident, while the effects of light intensity on sexual maturity are not quite as clear. Much of the work that has been conducted with light intensity and sexual maturity has been with turkeys. Siopes (1991) determined that there is a wide range of light intensities to which reproductive functions of turkeys respond similarly and that it appears that once a light intensity of 54 lux is achieved, sufficient light reaches the photoperiodic apparatus to maximally stimulate reproductive function. Light intensity has long been used in controlling cannibalism in laying houses (Morris, 1967), but its effects on ovarian morphology at sexual maturity is not certain.

It was hypothesized that short days would delay sexual maturity and that high intensity would overstimulate the ovary resulting in an increased number of large yellow follicles. The objectives of this research project were to determine the effects of increasing day length alone and in combination with increased light intensity on age at sexual maturity, ovarian morphology, and carcass composition in broiler breeder pullets.

2.2 MATERIALS AND METHODS

2.2.1 Stocks and Management

A total of 120 Shaver Starbro broiler breeder pullets were reared in floor pens following recommended BW targets provided by Shaver Poultry Breeding Farms Ltd. (Cambridge, ON). Each pullet

was wingbanded at 4 wk of age. Feed was offered *ad libitum* until 3 weeks of age, at which time a skip-a-day feeding program was implemented. Water was provided *ad libitum*. During rearing, the photo schedule was 8L:16D and a mean light intensity of 3.4 lux, measured at the level of the bird.

At 20 wk of age, the 64 pullets closest to the flock mean were housed in individual cages in one of four light-tight environmental chambers. The cages were specially constructed for a project of this type; each cage was illuminated by a dimmable overhead incandescent bulb. This housing arrangement provided more uniform lighting to each bird than is achievable in floor-housed poultry. Intensity was measured at the level of the feeder. The birds within each of the chambers were exposed to one of two light intensities, 10 lux (Low, L) or 100 lux (High, H) and one of two photo schedules, 8L:16D (Short, S) or 15L:9D (Long, L). The four treatment combinations were as follows: high intensity, long days (HL); high intensity, short days (HS); low intensity, long days (LL); and low intensity, short days (LS).The birds remained feed restricted while individually caged at the level needed to maintain BW as recommended by the breeder. Beginning at 20 wk, the same feeding allotments were provided to all four rooms.

Each of the 64 pullets was killed by cervical dislocation on the day following first oviposition. During the period from 20 wk until they were killed, each bird was individually weighed and blood sampled via brachial venipuncture, at weekly intervals. Ten ml of blood was collected using a heparin-primed vacuum collection tube and a 21 gauge needle. The blood was centrifuged at 1500 rpm for 15 min at 3°C, and plasma was harvested. Plasma was stored at -30°C for subsequent radio immunoassay (RIA) determination of plasma estradiol-17β concentration. The estradiol-17β content was measured using a solid-phase RIA obtained from Diagnostics Products Corp. (Los Angeles, California). Parallelism in the RIA was determined by measuring the estradiol-17β concentration in different volumes of plasma samples. The concentration of estradiol-17β was (mean±SEM) 31±3.0, 101.8±6.8, 247.6±8.4, and 599.5±14.0 pg/mL, for 50, 100, 200, and 400 μL of plasma sample. Two hundred μL of each plasma sample was analysed in duplicate. The allowable percent difference between duplicates was 5%. The samples were analysed in four assays. The inter-assay coefficient of variation was 3.15% and the intra-assay coefficient of variation was 5.24%. The sensitivity of the assay was 1.5 pg/mL. The antiserum was highly specific for estradiol-17β with a relatively low cross reactivity to other naturally occurring steroids in the plasma sample as stated by the manufacturer. All tested compounds

had a cross reactivity less than 1% with the exception of *d*-Equilenin (4.4%), estrone (10%), and estrone-β-D-glucuronide (1.8%). Plasma estradiol-17β concentrations were determined at 22 wk, 24 wk, and at sexual maturity.

2.2.2 *Carcass Examinations*

After euthanization, shank length and BW were recorded. Shank length was measured as the distance from the middle of the foot pad to the hock joint. Data collected on the dissected carcass included breast muscle wt *(Pectoralis major* and *Pectoralis minor*), liver wt, abdominal fat pad wt (including fat adhering to the gizzard), oviduct wt, and ovary wt. All organ weights were expressed as an absolute wt as well as a % of BW.

The ovary was further dissected into number of large yellow follicles (LYF; diameter>10mm), number of small yellow follicles (SYF; 5-10mm in diameter), and stroma. The number of LYF was recorded and each was individually weighed. The number of SYF and stroma wt (ovary minus LYF) were also recorded. Paired LYF were calculated as the percentage of LYF in the hierarchy within 1 g of each other. The F1 follicle was not included in determining paired LYF. A corrected ovary wt was calculated by subtracting the F1 follicle wt from the total ovary wt to take into account birds that may have ovulated just prior to processing and hence, would have a lower ovary weight than birds that had not ovulated that day.

Each carcass (minus the liver) was stored at -10°C pending subsequent analysis following the procedure of Yu *et al* (1990) for whole body composition. Each carcass was softened for 4 h in a pressure cooker and then homogenized in an industrial blender. A 500 mL subsample of homogenate of each bird was freeze dried and ground in a small coffee blender. After freeze drying, chemical analysis for moisture content, total crude protein, petroleum-ether extracted lipid, and total ash was conducted in duplicate on each sample (Association of Analytical Chemists, 1980). Livers were kept separate from the carcass, freeze dried and homogenized, and analysed for lipid concentration. The allowable differences between duplicate samples were 2% for carcass lipid, dry matter, and crude protein, and 5 % for ash and liver lipids. Three birds were excluded from the data set. Two birds from the HS interaction and one bird from the LS interaction were culled for skeletal problems.

2.2.3 Statistical Analysis

Two-way Analysis of Variance with the main effects, light intensity and photo schedule, and the light intensity*photo schedule interaction were computed using the General Linear Models Procedure of SAS (SAS Institute, 1994). Statements of significance among the light intensity*photo schedule means were evaluated using the Least Significant Difference t-test (Steel and Torrie, 1980) and are based on $P \leq 0.05$, unless otherwise stated. The experiment proposal was reviewed and approved by the Faculty Animal Policy and Welfare Committee of the Faculty of Agriculture, Forestry, and Home Economics of the University of Alberta.

2.3 RESULTS AND DISCUSSION

The were no differences in age at sexual maturity for the main effect of light intensity. Birds exposed to short days attained sexual maturity at an older age (195.3 d) than did birds that were photostimulated (long day) (182.3 d) as shown in Table 2-1. This supports the hypothesis, though the delay was not as great as expected. Lupicki (1994) observed a similar trend and reported that photostimulated broiler breeders attained sexual maturity 40 d before non-photostimulated broiler breeders. The light intensity*photo schedule interaction did not have any effect on age at sexual maturity, but the treatment combinations including short days reached sexual maturity at an older age than birds in the treatment combinations including long days.

Results of BW, shank length, breast wt, and abdominal fatpad wt at sexual maturity are shown in Table 2-2. It was observed that there were no differences in BW at sexual maturity between the two light intensities. However, for photo schedule, short day birds were 360 g heavier at sexual maturity than long day birds. As a result of short day birds not being photostimulated, nutrients from the diet may have gone to lean body mass and fat deposition rather than to reproductive processes, hence the greater BW. It also makes sense for the short day birds to be heavier as they were older when they reached sexual maturity. These results are supported by Lupicki (1994) who also observed that non-photostimulated birds were heavier than photostimulated birds at sexual maturity. Body weight at sexual maturity was not affected by the light intensity*photo schedule interaction. Brody *et al* (1980) suggested that the onset of lay in poultry may require that the birds first reach some minimum body size. Results for BW at sexual maturity for this

experiment do not indicate that there is threshold BW required for the attainment of sexual maturity, at least for the BW range observed.

Shank length did not differ for the main effects or for the light intensity*photo schedule interaction with the mean value being 109 mm (Table 2-2). Shank length measurements agree with results reported by Robinson *et al* (1996). Breast muscle wt and abdominal fatpad wt were not significantly different for light intensity or for the light intensity*photo schedule interaction, but they were for photo schedule. Breast muscle wt on an absolute basis was less in long day birds (424.0 g) than short day birds (498.1 g), while breast as a % of BW was not different, 16.06% and 16.62%, respectively. Fat pad wt both on an absolute basis and as a % of BW was greater in short day birds than long day birds.

In terms of reproductive traits (Table 2-3), there were no differences for oviduct wt, ovary wt, stroma wt, number of SYF, number of LYF, or % paired LYF for any of the treatments. Although not significantly different, it was interesting to observe the trend with the number of LYF for the light intensity*photo schedule interaction. There was a gradual increase in numbers from the "least stimulated" (LS) to "most stimulated" (HL). The number of LYF reported for the main effect light intensity does not agree with the hypothesis of the ovary being overstimulated and hence result in a greater number of LYF when birds are exposed to high intensity. Though LYF numbers were slightly greater for high intensity birds (7.2) than low intensity birds (6.8), it was not significant. There was also a numerically greater incidence of % paired LYF for high intensity birds. Hocking *et al* (1989) stated that the number of yellow follicles at first egg may be more closely related to lean than to BW. The results of this experiment agree with this statement as there were no differences in lean BW (carcass protein), and hence, no differences in large yellow follicle numbers.

The results for carcass composition analysis are in tabulated in Table 2-4. Short day birds had a greater carcass water wt on an absolute basis, while long day birds had a greater carcass water wt as a % of BW. Carcass protein wt was less in long day birds than short day birds, while percent carcass protein was not different. Carcass fat was greater on an absolute basis as well as a % of BW for short day birds than long day birds. Percent carcass ash was greater on the long day birds (3.49%) than short day birds (3.19%). Neither absolute wt or % of BW of carcass protein and carcass fat were different for the light intensity*photo schedule interaction, but the values were quite constant. There have been many experiments conducted to

determine the factors that affect the attainment of sexual maturity in chickens. It has been concluded that a minimum lean body mass (Soller *et al*, 1984) and/or a minimum body fat pool (Bornstein *et al*, 1984) are determinants or initiators of the onset of egg production in broiler breeders. From the results of this experiment, it appears that a minimum lean mass and fat pool are required as neither % carcass protein nor % carcass lipids were different at sexual maturity. It does not appear that any one factor is responsible for the onset of sexual maturity in chickens, but rather, it is a combination of factors such as age, BW, fat content, and lean body mass.

Table 2-5 shows results for liver wt and liver lipids at sexual maturity. While liver wt was not different on an absolute basis or as a % of BW for light intensity or photo schedule, it was different for the treatment combinations with the values being: HL (44.0 g; 1.70 %), HS (50.6 g; 1.72%), LL (49.8 g; 1.85%), and LS (48.7 g; 1.63%). The treatment combinations involving short days and low intensity have greater liver weights than the high intensity*long day treatment combination. These birds were also older and had a heavier BW at sexual maturity. Reasons for liver wt being different could be that these birds had a higher lipid content is possibly due to consumption of more feed as a result of these birds attaining sexual maturity later. Liver lipids expressed as a wt, % of liver, and % of BW did not differ for any of the treatments.

Plasma estradiol-17β concentrations are shown in Table 2-6. Concentrations were significantly different between the two photo schedules, as they were significantly lower at 22 wk, 24 wk, and at sexual maturity for the birds that were not photostimulated. Estradiol-17β is produced in increasing amounts by the pool of small follicles on the ovary in response to increasing plasma LH levels which are stimulated by increasing day length (Robinson and Etches, 1986). Increasing day length should result in the production of greater amounts of estradiol-17β, which is what the results indicate although not significantly different. Plasma estradiol-17β concentrations were greater, at each age measured, for those light intensity*photo schedule treatment combinations involving long days. Levels of plasma estradiol-17β at sexual maturity agree with values published by Johnson (1986).

This study has shown that there are many factors that contribute to the attainment of sexual maturity in broiler breeder pullets. It is not any one of these factors alone that predominates, but it is the combination of these factors. Day length, especially increasing day length, plays a major role in the onset of sexual

maturity. Numerous experiments have been conducted concluding that BW (Bornstein *et al*, 1984, Brody *et al*, 1980, 1984), body fat (Bornstein *et al*, 1984), lean body mass (Soller *et al*, 1984), and to some degree, age (Brody *et al*, 1980, 1984) play a part in the attainment of sexual maturity. In general, short days delay the attainment of sexual maturity. Although birds will reach sexual maturity while maintained on short days, it is still beneficial to photo stimulate in order to achieve maximum reproductive efficiency. It appears that light intensity above 10 lux does not have a significant impact on reproductive or carcass characteristics, as light intensity had no effect on any trait measured. It may be of use to repeat this trial, but to have varying light intensities and also to keep some birds throughout the laying period for production records. The light intensity during rearing would also be required to be lower than either of the treatment light intensities.

Table 2-1. Effects of light intensity and photo schedule on age at sexual maturity (SM) (Mean±SEM)

	n[1]	Age at SM, d
Main Effects		
Light Intensity		
High (H)	30	187.2±1.8*a*
Low (L)	31	190.3±1.8*a*
Photo Schedule		
Long (L)	31	182.3±1.8*a*
Short (S)	30	195.3±1.8*b*
Light Intensity*Photo Schedule		
HL	15	181.0±2.5*b*
HS	15	193.5±2.5*a*
LL	16	183.6±2.4*b*
LS	15	197.1±2.5*a*

a,b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly ($P<0.05$)

[1]n=number of birds in each treatment

Table 2-2. Effects of light intensity and photo schedule on BW, shank length, breast wt, and abdominal fat pad wt at sexual maturity (SM) (Mean±SEM)

				Breast wt[2]		Abdominal fatpad wt	
	n[1]	BW, g	Shank length, mm	g	% BW	g	% BW
Main Effects							
Light Intensity							
High (H)	30	2744±41*a*	108.7±0.8*a*	456.0±10.6*a*	16.38±0.21*a*	52.7±3.6*a*	1.87±0.11*a*
Low (L)	31	2826±40*a*	109.5±0.8*a*	466.1±10.5*a*	16.30±0.21*a*	53.0±3.5*a*	1.82±0.11*a*
Photoschedule							
Long (L)	31	2603±40*a*	109.0±0.8*a*	424.0±10.5*a*	16.06±0.21*a*	41.9±3.5*a*	1.58±0.11*a*
Short (S)	30	2967±41*b*	109.1±0.8*a*	498.1±10.6*b*	16.62±0.21*a*	63.8±3.6*b*	2.11±0.11*b*
Light Intensity*Photo Schedule							
HL	15	2551±58*b*	108.4±1.1*a*	418.2±15.0*b*	16.15±0.30*a*	40.4±5.1*b*	1.56±0.16*b*
HS	15	2937±58*a*	108.9±1.1*a*	493.8±15.0*a*	16.61±0.30*a*	65.1±5.1*a*	2.18±0.16*a*
LL	16	2656±56*b*	109.7±1.1*a*	429.8±14.6*b*	15.97±0.29*a*	43.5±4.9*b*	1.59±0.15*b*
LS	15	2996±58*a*	109.4±1.1*a*	502.3±15.0*a*	16.62±0.30*a*	62.5±5.1*a*	2.05±0.15*a*

a,b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly($P<0.05$)

[1]n=number of birds in each treatment

[2]Breast weight=wt of *Pectoralis major* and *Pectoralis minor*

Table 2-3. Effects of light intensity and photo schedule on oviduct wt, ovary wt, stroma wt, #SYF, #LYF, and % paired LYF at sexual maturity (SM) (Mean±SEM)

		Oviduct wt		Ovary wt		Stroma wt				
	n[1]	g	% BW	g	% BW	g	% BW	#SYF[2]	#LYF[3]	% Paired LYF[4]
Main Effects										
Light Intensity										
High (H)	30	65.5±1.6*a*	2.34±0.05*a*	46.3±1.9*a*	1.68±0.07*a*	6.8±0.4*a*	0.24±0.01*a*	9.6±0.8*a*	7.2±0.2*a*	24.02±4.28*a*
Low (L)	31	65.3±1.5*a*	2.30±0.05*a*	44.5±1.9*a*	1.57±0.07*a*	7.2±0.4*a*	0.25±0.01*a*	10.2±0.7*a*	6.8±0.2*a*	20.51±4.21*a*
Photo schedule										
Long (L)	31	64.8±1.5*a*	2.46±0.05*a*	44.4±1.9*a*	1.69±0.07*a*	6.7±0.4*a*	0.25±0.01*a*	9.5±0.8*a*	7.2±0.2*a*	29.73±4.21*a*
Short (S)	30	66.0±1.6*a*	2.22±0.05*a*	46.3±1.9*a*	1.56±0.07*a*	7.4±0.4*a*	0.25±0.01*a*	10.3±0.8*a*	6.8±0.2*a*	14.80±4.21*b*
Light Intensity*Photo Schedule										
HL	15	65.2±2.2*a*	2.51±0.07*a*	45.1±2.7*a*	1.74±0.10*a*	6.1±0.5*a*	0.24±0.02*a*	8.6±1.1*a*	7.4±0.3*a*	29.24±6.05*a*
HS	15	65.7±2.2*a*	2.23±0.07*a*	47.4±2.7*a*	1.61±0.10*a*	7.5±0.5*a*	0.25±0.02*a*	10.5±1.1*a*	7.0±0.3*a*	18.81±6.05*ab*
LL	16	64.5±2.1*a*	2.41±0.07*a*	43.7±2.7*a*	1.63±0.10*a*	7.2±0.5*a*	0.27±0.02*a*	10.4±1.0*a*	6.9±0.3*a*	30.23±5.86*a*
LS	15	66.2±2.2*a*	2.20±0.07*a*	45.3±2.7*a*	1.50±0.10*a*	7.2±0.5*a*	0.24±0.02*a*	10.1±1.1*a*	6.6±0.3*a*	10.79±6.05*b*

a,b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]#SYF=number of small yellow follicles (5-10 mm diameter)

[3]#LYF=number of large yellow follicles (>10 mm diameter)

[4]%Paired LYF=percent of large yellow follicles within 1 g of one another

Table 2-4. Effects of light intensity and photo schedule on carcass composition at sexual maturity (SM) (mean ± SEM)

		Water		Protein		Fat		Ash	
	n[1]	g	% BW	g	% BW	g	%BW	g	% BW
Main Effects									
Light Intensity									
High (H)	30	1662.5±23.7*a*	62.20±0.32*a*	562.7±8.0*a*	21.04±0.12*a*	340.0±14.4*a*	12.55±0.41*a*	90.7±1.9*a*	3.40±0.06*a*
Low (L)	31	1728.6±23.3*a*	62.84±0.32*a*	575.4±7.9*a*	20.92±0.12*a*	339.3±14.2*a*	12.17±0.41*a*	89.9±1.9*a*	3.28±0.06*a*
Photo schedule									
Long (L)	31	1605.0±23.3*a*	63.35±0.32*a*	534.1±7.9*a*	21.10±0.12*a*	285.1±14.2*a*	11.21±0.41*a*	88.2±1.9*a*	3.49±0.06*a*
Short (S)	30	1786.1±23.7*b*	61.68±0.32*b*	604.1±8.0*b*	20.85±0.12*a*	394.1±14.4*b*	13.51±0.41*b*	92.3±1.9*a*	3.19±0.06*b*
Light Intensity*Photo Schedule									
HL	15	1572.9±33.5*b*	63.23±0.45*ab*	527.3±11.3*b*	21.20±0.17*a*	279.0±20.4*b*	11.24±0.59*b*	87.7±2.7*a*	3.52±0.09*a*
HS	15	1752.0±33.5*a*	61.16±0.45*c*	598.2±11.3*a*	20.87±0.17*a*	400.9±20.4*a*	13.86±0.59*a*	93.7±2.7*a*	3.28±0.09*a*
LL	16	1637.1±33.4*b*	63.48±0.44*a*	540.9±10.9*b*	21.00±0.16*a*	291.2±19.8*b*	11.18±0.57*b*	88.8±2.6*a*	3.46±0.09*a*
LS	15	1820.2±33.5*a*	62.20±0.45*b*	609.9±11.3*a*	20.84±0.17*a*	387.3±20.4*a*	13.16±0.59*a*	91.0±2.7*a*	3.11±0.09*b*

a,b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly ($P<0.05$)
[1]n=number of birds in each treatment

Table 2-5. Effects of light intensity and photo schedule on liver wt and liver lipids at sexual maturity (SM) (Mean±SEM)

		Liver wt		Liver lipids		
	n[1]	g	%BW	g	% Liver	%BW
Main Effects						
Light Intensity						
High (H)	30	47.3±1.2*a*	1.71±0.04*a*	3.8±0.5*a*	7.69±0.86*a*	0.13±0.02*a*
Low (L)	31	49.3±1.2*a*	1.74±0.04*a*	4.3±0.5*a*	8.53±0.83*a*	0.15±0.02*a*
Photo schedule						
Long (L)	31	46.9±1.2*a*	1.78±0.04*a*	3.4±0.5*a*	7.02±0.83*a*	0.13±0.02*a*
Short (S)	30	49.7±1.2*a*	1.67±0.04*a*	4.7±0.5*a*	9.19±0.86*a*	0.16±0.02*a*
Light Intensity*Photo Schedule						
HL	15	44.0±1.7*b*	1.70±0.06*ab*	2.6±0.7*b*	5.86±1.19*b*	0.10±0.02*a*
HS	15	50.6±1.7*a*	1.72±0.06*ab*	5.0±0.7*a*	9.51±1.23*a*	0.16±0.03*a*
LL	16	49.8±1.6*a*	1.85±0.06*a*	4.3±0.7*ab*	8.18±1.15*ab*	0.16±0.02*a*
LS	15	48.7±1.7*a*	1.63±0.06*b*	4.4±0.7*ab*	8.87±1.19*ab*	0.16±0.02*a*

a,b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly ($P<0.05$)

[1]n=number of birds in each treatment

Table 2-6. Effects of light intensity and photo schedule on plasma estradiol - 17β concentrations (pg/mL) at 22 wk, 24 wk, and sexual maturity (Mean±SEM)

		Plasma estradiol 17β concentrations (pg/mL)		
	n[1]	22 wk.	24 wk.	Sexual Maturity
Main Effects				
Light Intensity				
High (H)	30	76.6±6.4*a*	99.9±9.8*a*	101.4±8.7*a*
Low (L)	31	71.4±6.3*a*	83.3±9.7*a*	113.7±8.5*a*
Photo schedule				
Long (L)	31	88.9±6.3*a*	111.5±9.7*a*	121.6±8.5*a*
Short (S)	30	59.0±6.4*b*	71.7±9.8*b*	93.5±8.7*b*
Light Intensity*Photo Schedule				
HL	15	88.8±9.0*ab*	116.6±13.9*a*	127.4±12.2*a*
HS	15	64.3±9.0*ab*	83.1±13.9*ab*	75.4±12.2*b*
LL	16	89.0±8.7*a*	106.3±13.4*a*	115.8±11.9*a*
LS	15	53.7±9.0*b*	60.3±13.9*b*	111.6±12.2*a*

a.b Means within a column for each main effect and Light Intensity*Photo Schedule with no common alphabetic letter differ significantly (P<0.05)
[1]n=number of birds in each treatment

2.4 REFERENCES

Association of Official Analytical Chemists. 1980. Official Methods of Analysis, 13th ed. AOAC, Washington, DC.

Bornstein, S., Plavnik, I., and Lev, Y. 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci. **25**: 323-341.

Brody, T., Eitan, Y., Soller, M., Nir, I., And Nitsan, Z. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sci. **21**: 437-446.

Brody, T.B., Siegel, P.B., and Cherry, J.A. 1984. Age, body weight and body composition requirements for the onset of sexual maturity of dwarf and normal chickens. Br. Poult. Sci. **25**: 245-252.

Etches, R.J. 1996. Reproduction in Poultry. CAB International, Wallingford UK.

Hocking, P.M., Waddington, D., Walker, M.A., and Gilbert, A.B. 1989. Control ot the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. Br. Poult. Sci. **30**: 161-174.

Johnson, A.L. 1986. Reproduction in the female. Pages 432-451 *in*: Avian Physiology. P.D. Sturkie, ed. Springer-Verlag, New York.

Lupicki, M. 1994. Ovarian morphology and steroidogenesis in domestic fowl (*Gallus domesticus*): Effects of aging, strain, photostimulation program, and level of feeding. M.Sc. Thesis. University of Alberta, Edmonton, AB.

Morris, T.R. 1967. The effect of light intensity on growing and laying pullets. World's Poult. Sci. J. **23**: 246-252.

Robinson, F.E. and Etches, R.J. 1986. Ovarian steroidogenesis during follicular maturation in the domestic fowl (Gallus domesticus). Biol. Reprod. **35**: 1096-1105.

Robinson, F.E., Wautier, T.A., Hardin, R.T., Robinson, N.A., Wilson, J.L., Newcombe, M, and McKay, R.I. 1996. Effects of age at photostimulation on reproductive efficiency and carcass characteristics. 1. Broiler breeer hens. Canadian Journal of Animal Science **76**: 275-282.

SAS Institute. 1994. The SAS System for Windows 3.10, Release 6.10. Cary, N.C. 27513, U.S.A.

Siopes, T.D. 1991. Light intensity effects on reproductive performance of turkey breeder hens. Poult. Sci. **70**: 2049-2054.

Soller, M., Eitan, Y., and Brody, L. 1984. Effect of diet and early quantitative feed restriction on the minimum weight requirement for onset of sexual maturity in White Rock broiler breeders. Poult. Sci. **63**: 1255-1261.

Steel, R.G.D., and Torrie, J.H. 1980. Principles and Procedures of Statistics. 2nd edition. McGraw-Hill Book Co. Inc., New York, NY.

Yu, M.W., Robinson, F.E., Clandinin, M.T., and Bodnar, L. 1990. Growth and body composition of broiler chickens in response to different regimes of feed restriction. Poult. Sci. **69**: 2074-2081.

3. EFFECT OF STRAIN, FEEDING PROGRAM, AND PHOTO STIMULATION PROGRAM ON CARCASS TRAITS AND OVARIAN MORPHOLOGY AT PHOTO STIMULATION AND AT SEXUAL MATURITY IN FEMALE BROILER BREEDERS

3.1 INTRODUCTION

Quantitative feed restriction has become the industry standard for controlling BW in broiler breeders. Feed restriction is a necessary management tool when dealing with broiler breeders as these birds have a tendency to become obese when allowed *ad libitum* access to feed. There have been numerous studies confirming the strong negative relationship between BW and reproductive efficiency in domestic poultry (Robinson *et al*, 1993). Although feed restriction delays sexual maturity in broiler breeders (Yu *et al*, 1992a; Lupicki, 1994), it is clear that feed restriction is beneficial in reducing large yellow follicle numbers (Hocking et al, 1987, 1989; Yu *et al*, 1992b; Lupicki, 1994), which could result in fewer double hierarchies, and hence, better overall egg production.

The effects of photo stimulation program and rate of feed allocation program from 20 to 25 wk of age on carcass traits and ovarian morphology at sexual maturity in commercial broiler breeder pullets was investigated by Robinson *et al* (1995). It was found that a fast feeding program resulted in more large yellow follicles leading to a heavier ovary weight when compared to a slow feeding program. As well, the slow photoperiod resulted in a greater ovary weight than the fast photoperiod, while there were no effects of either of the main effects on age at sexual maturity.

Little work has been done investigating differences in broiler breeder strains in terms of carcass composition and ovarian morphology at the time of sexual maturity. There also is not much documentation on the effects small increases in feed may have on ovarian form and function. The objectives of this experiment were to determine the effects of strain, feeding program, and photo stimulation program on carcass traits and ovarian morphology at photo stimulation and at sexual maturity in broiler breeder pullets.

3.2 MATERIALS AND METHODS

3.2.1 Stocks and Management Before 20 wk of Age

Four hundred pullets of each of two strains, Shaver Starbro (SS) and an Experimental Line (EL) carrying approximately 3% more breast muscle than the Starbro, were reared strain-separately in floor pens (4.72 m x 5.79 m). The mean stocking density per pen was 145 pullets per pen. Water was provided *ad libitum* from two bell drinkers per pen. All birds were fed *ad libitum* until 3 wk of age at which time a skip-a-day feeding program was implemented. Following recommended guidelines, all pullets were beak-trimmed at 1 wk of age and wing-banded at 3 wk of age. Each wk, group weights of each pen were performed to determine bird numbers, average BW, and hence weekly feed allocations. Both strains were managed according to Shaver Starbro guidelines for BW and feed allocation. Every bird was individually weighed at 4 wk intervals (4, 8, 12, 16, and 20 wk). Excessively small birds were culled from the flock starting at 12 wk of age. The birds were fed a starter diet from 0 to 3 wk of age, a grower diet from 3 to 20 wk of age, and a layer diet from 20 wk of age to processing (Table 3-1). On day 1, the pullets received 24 h of light (24L:0D) and from day 2 to 20 wk of age, received 8 h of light per day (8L:16D) until photo stimulation.

3.2.2 Stocks and Management After 20 wk of Age

At 20 wk of age, all birds were individually weighed and the 408 birds (204 of each strain) closest to the target BW were individually caged and randomly assigned to one of four treatment groups. The treatment groups were feeding program, Fast Feed (FF) or Slow Feed (SF), and photo stimulation program, Fast Photoperiod (FP) or Slow Photoperiod (SP), which commenced at 21 wk of age. The fast and slow feed programs basically differed in the rate of increase of weekly feed allocations. Fast feed was a more aggressive approach while slow feed was more conservative. Fast photoperiod was an abrupt change in the amount of light per day from 8L:16D to 15L:9D, while the slow photoperiod consisted of a gradual increase of light as follows: 11L:13D (21 wk), 12L:12D (22 wk), 13L:11D (23 wk), 14L:11D (24 wk), and 15L:9D (25 wk). At 25 wk of age, both the fast and slow photoperiods were the same (15L:9D). The experimental design was a 2 by 2 by 2 factorial with the main effects of strain [Shaver Starbro (SS) or Experimental Line (EL)], feeding program [Fast Feed (FF) or Slow Feed (SF)], and photo stimulation program [Fast Photoperiod (FP) or Slow

Photoperiod (SP)]. The birds within each treatment combination were assigned to one of three groups which differed in the times at which processing was done (Table 3-2). The groups were designated as A-Group, B-Group, or C-Group. There were 20 birds per strain for A-Group birds, which were killed at photo stimulation. Ten birds per strain by feeding program by photo stimulation program interaction were designated to the B-Group, killed the day following first oviposition. C-Group birds consisted of 36 birds per interaction and were retained for individual production data and were killed at 60 wk of age (data presented in Chapter 4).

All birds chosen for the project were housed individually in the same room at 20 wk of age to acclimatise them before experimental treatments commenced. In order to have both the slow and fast photoperiods in the same room, a light-tight impermeable black polyethylene wall was constructed at 20 wk of age. This wall was removed at 25 wk of age, when both photoperiods were the same. A dusk-to-dawn lighting apparatus, which simulates a natural light environment, by the lights turning on and off gradually, was the source of light in the barn. While the wall was up, the room temperature of each side was recorded twice a day (am and pm) and continued to be monitored when the wall was taken down. Room temperature was maintained between 16 and 23 °C.

All birds were fed individually from 20 wk of age until processing. Individual BW were recorded weekly in order to allocate feed. As a rule of thumb, feed allocations generally did not exceed 6 g/bird/wk. When required to exceed 6 g/wk, multiple increases of 2 or 3 g were made. Feed was weighed using an automated feed allocation system (Feddes *et al*, 1995). Each B-Group bird was individually weighed at the time she reached sexual maturity (first oviposition) and the egg was weighed as well.

3.2.3 Carcass Examinations

Each bird was euthanised for body composition analysis. A-Group birds were studied at photo stimulation (21 wk) while B-Group birds were studied the day following first oviposition, in a similar manner to the birds described previously in Chapter 2. Briefly, following euthanisation, BW and shank length were recorded. Data was collected on the dissected carcass determining breast muscle wt (*Pectoralis major* and *Pectoralis minor*), liver wt, abdominal fat pad wt (including fat adhering to the gizzard), oviduct wt, and

ovary wt as conducted routinely at the University of Alberta. All organ weights were expressed as an absolute basis as well as a % of BW.

For the B-Group birds, the ovary was further dissected to yield the number of large yellow follicles (LYF; diameter>10mm), number of small yellow follicles (SYF; 5-10 mm in diameter), and stroma (ovary wt less LYF). Paired LYF were calculated as the percentage of LYF, not including the F1 follicle, in the hierarchy within 1 g of each other. A corrected ovary wt was also calculated. This was done by subtracting the F1 follicle wt from the total ovary wt to take into account birds which may have ovulated just prior to processing. The corrected ovary wt was then used in subsequent analyses.

Each carcass was softened for 3 to 4 h in a pressure cooker and then homogenized in an industrial blender. A 500 mL subsample of homogenate of each bird was freeze dried and ground in a small coffee blender. Chemical analysis for moisture content, total crude protein, petroleum-ether extracted lipid, and total ash was conducted in duplicate on each sample (Association of Analytical Chemists, 1980). The allowable differences between duplicate samples were 2% for carcass lipid, dry matter, and crude protein, and 5 % for ash and liver lipids.

Two birds from the B-Group were excluded from the data set. One was culled as a result of skeletal problems and the other was culled as it did not attain sexual maturity in the time period allotted (3 wk after the previous bird).

3.2.4 Statistical Analysis

Data for the A-Group birds were subjected to a one-way Analysis of Variance for the main effect, strain. Data for the B-Group birds were subjected to a three-way Analysis of Variance for the main effects strain (d.f.=1), feeding program (d.f.=1), and photo stimulation program (d.f.=1) and the pooled strain*feeding program, strain*photo stimulation program, feeding program*photo stimulation program, and strain*feeding program*photo stimulation interactions (d.f.=4) program using the General Linear Models Procedure of SAS (SAS Institute, 1994). The significant differences among the strain*feeding program*photo stimulation program means were determined using the Least Significant Difference t-test (Steel and Torrie, 1980) and are based on $P \leq 0.05$, unless otherwise stated. Pearson correlation coefficients of

the interrelationships among traits were computed for both the A-Group and B-Group birds. The experiment proposal was reviewed and approved by the Faculty Animal Policy and Welfare Committee of the Faculty of Agriculture, Forestry, and Home Economics of the University of Alberta.

3.3 RESULTS AND DISCUSSION

3.3.1 A-Group Birds -Processed at Photo Stimulation

The main effect of strain had a significant effect on both BW and shank length (SS: BW=1959 g, shank=102.7 mm; EL: BW=1867 g, shank=101.7 mm) at photo stimulation (Table 3-3). The SS birds had a higher BW as well as a longer shank length than EL birds indicating a greater frame size at the time of photo stimulation. The main effect of strain did not have any effects on liver wt or abdominal fatpad wt for either absolute wt or as a % of BW at photo stimulation. Although there were no differences for liver wt and fat pad wt for the strains, both were positively correlated with BW, r=0.143 and r=0.571, respectively. Experimental Line birds had a numerically heavier absolute breast muscle wt than the SS birds, while breast wt as a % of BW was significantly greater for the EL birds. Absolute breast wt was very highly correlated to BW (r=0.734).

Strain did not have a significant effect on reproductive tract characteristics at photo stimulation (Table 3-4). Neither ovary wt nor oviduct wt were different between the strains for absolute wt or % of BW. Both ovary wt (r=0.509) and oviduct wt (r=0.451) were positively correlated with BW at photo stimulation.

There were no strain differences for any of the carcass composition parameters measured (Table 3-5). The EL birds did have numerically higher values for absolute wt for carcass water, protein, fat, and ash content while these birds had a significantly lighter BW at photo stimulation.

3.3.2 B-Group Birds - Processed at Sexual Maturity

Body weight at sexual maturity (Table 3-6) was not different for the main effects of strain or feeding program, but it was different for photo stimulation program with the SP birds (2789 g) having a greater BW than FP birds (2680 g). For the interaction of strain*feeding program*photo stimulation program, there were no differences in BW at sexual maturity, but the treatment combinations with SP program birds generally had

numerically greater BW. Shank length did not differ for any of the main effects or for the strain*feeding program*photo stimulation program interaction, although it did approach significance (P=0.085) for strain, with the SS birds having a longer shank length.

Liver wt (Table 3-6) as an absolute basis at sexual maturity was greater for SS birds (51.3 g) than for EL birds (47.9 g), but was not different when expressed as a % of BW. The main effect of feeding program had a significant effect on liver wt as an absolute value with the FF birds having a greater liver wt (51.6 g) than SF birds (47.7 g). The same pattern was seen for liver wt expressed as a % of BW (FF: 1.89 %; SF: 1.75 %). Although the differences in feed allocation from 21 to 25 wk of age were small, it appears that the FF program birds, which received more feed, may have had a higher liver fat content and hence, a greater liver wt. Neither photo stimulation program nor the strain*feeding program*photo stimulation program interaction had any effect on liver wt.

As with the birds at photo stimulation, breast muscle wt (Table 3-6) as a % of BW at sexual maturity was significantly greater for the EL birds (17.28 %) than the SS birds (15.83 %). Also, absolute breast muscle wt was also greater in the EL birds (468.2 g) than the SS birds (437.9 g). Similarly with the A -Group birds, absolute breast wt was highly correlated with BW (r=0.732). The main effects of feeding program and photo stimulation program as well as the interaction of the main effects did not have an effect on breast wt as an absolute basis or as a % of BW.

The main effects and the interaction did not have any effect on abdominal fat pad wt (Table 3-6) at sexual maturity. Fat pad wt was found to be highly positively correlated with carcass fat content (r=0.633) at sexual maturity, while it was not as highly correlated with BW (r=0.463) at sexual maturity.

Both strains reached sexual maturity (Table 3-7) within 2 d of each other (EL: 175.2 d; SS: 177.6 d), which was not significantly different. Fast fed birds attained sexual maturity at 173.6 d of age, 6 d earlier than SF birds. This is most likely due to the fact that FF birds would have been receiving more nutrients from the diet as a result of the higher feed allocation between 21 and 25 wk of age which would aid in reaching any minimum lean mass, fat content, or BW requirements. Photo stimulation program was not different in terms of the age at sexual maturity, with FP birds reaching sexual maturity at 175.3 d and SP birds at 177.4 d. There were no significant differences for the strain*feeding program*photo stimulation program

interaction for sexual maturity. Overall, age at sexual maturity was found to be positively correlated with BW (r=0.780).

Reproductive tract characteristics (ovary wt, oviduct wt, stroma wt, number of LYF, number of SYF, and % Paired LYF) are presented in Table 3-7. Numbers reported for SYF and LYF for the commercial strain (SS), are well within the range of values reported in previous studies (Yu *et al*, 1992b; Robinson *et al*, 1995; Hocking, 1993). The main effect of strain was the only effect that exhibited a significant difference in the number of SYF at sexual maturity with EL birds having 10.9 SYF and SS birds 13.6 SYF. The number of LYF at sexual maturity were 8.2 for EL birds and 8.1 for SS birds. Fast fed birds had 8.4 LYF on the ovary at sexual maturity while SF birds had 8.0 LYF. There were 8.2 LYF for FP birds and 8.1 LYF for SP birds. Unlike Robinson *et al* (1995) who found FF birds to have 1.0 more LYF than SF birds, the results of the present experiment indicated no differences in LYF numbers at sexual maturity for any of the main effects, but there were differences among the treatment combinations. Percent paired LYF were not different for any of the main effects, but SS birds had a higher % paired LYF (44.24 %) than EL birds (40.13 %) as did the FF birds (44.66 %) over the SF birds (39.17 %). Percent paired LYF refers to those LYF in the hierarchy which were with 1 g of wt of each other. At the time of ovulation, this may result in more than one LYF being ovulated since follicles of the same wt and size are most likely at the same stage of development and hence would ovulate at the same time. Multiple ovulations could result in the production of abnormal eggs such as double yolk, soft shell, or shelless eggs (Yu *et al*, 1992b; van Middelkoop, 1971 and 1972). The interactions involving SS and FF birds resulted in the highest % paired LYF numbers, which corresponds to the results seen for the main effects.

There were no significant differences observed for carcass composition (Table 3-8) for the main effects or for the strain*feeding program*photo stimulation program interaction at sexual maturity. Values were fairly consistent across all treatments for carcass water, protein, fat, and ash content. Carcass protein and fat were constant at about 20 % and 12 %, respectively. These constant values for carcass protein and fat support hypotheses and findings by Brody *et al* (1980) and Soller *et al* (1984) which state that a minimum lean body mass and/or carcass fat stores are required for the onset of sexual maturity. Carcass ash values were not significantly different for strain, but values were numerically higher for SS birds which may be indicative

of the result of having a larger frame size than EL birds. Upon comparing carcass composition results between the strains, from photo stimulation to sexual maturity, it was observed that the B-Group birds lost about 4 % in carcass water content and gained the same amount in carcass fat content. This increase in fat content stresses the importance of a minimum requirement for fat content in relation to the attainment of sexual maturity which is supported by Bornstein *et al* (1984). In a previous study by Wilson *et al* (1995) it was also observed that carcass water was reduced while carcass fat increased. The protein content of the carcass did not change greatly between photo stimulation and sexual maturity. One explanation for this could be that any requirements for lean body mass were already reached by the time of photo stimulation meaning that more than just lean body mass is required for the onset of sexual maturity in broiler breeder pullets. There appear to be minimum thresholds of lean mass and carcass fat that are required for the onset of sexual maturity. It seems that the requirement for fat is more important as lean requirements had already been achieved at the time of photo stimulation.

As consumer preferences and demands change, so must genetics. Since the trend today is toward eating healthier, genetic strains of chickens which carry more breast yield must be improved. Selecting for improved growth has a negative effect on reproductive traits, so genetics must also take into account reproductive efficiency of these birds. Management plays a major role here in determining how well a bird is going to produce. Although the EL birds were selected for greater breast mass, this does not appear to have affected reproductive traits, most likely due to the management strategies employed. Managing both strains following recommendations for the commercial strain appeared to be beneficial for both strains. Both strains attained sexual maturity at about the same age and BW. In terms of feeding program, although the FF birds attained sexual maturity before the SF birds, it seems that a SF program is more conducive to reproductive characteristics dealing with egg production. For instance, SF birds had numerically lower % paired LYF than FF birds would most likely result in fewer multiple ovulations, and hence, a greater overall egg production.

Table 3-1. Experimental design indicating the number of birds per treatment group

	Study period	Birds per interaction or strain	Total birds
A-Group	killed and blood sampled at photostimulation	n=20	40
B-Group	blood sampled at photostimulation and sexual maturity and killed at sexual maturity	n=10	80
C-Group	retained for production records and killed at 60 wk of age	n=36	288
Total			408

Table 3-2. Composition and analyses of experimental diets

Ingredients and Analyses	Starter (0 to 3 wk)	Grower (3 to 20 wk)	Layer (20 to 60 wk)
		%	
Ground wheat, Western	44.23	34.42	33.76
Ground corn	14.18	16.44	14.31
Ground oats, Ontario	5.00	12.50	10.00
Soybean meal (48% CP)	17.34	7.37	13.42
Ground barley, Ontario	5.00	10.00	15.00
Wheat shorts	7.50	15.00	1.29
Limestone	1.65	1.72	7.68
Dicalcium phosphate	1.58	0.86	1.06
Choline chloride premix[1]	0.50	0.50	0.50
Broiler premix[2]	0.50	0.50	---
Layer premix[3]	---	---	0.50
Salt	0.35	0.33	0.28
L-Lysine HCL	0.03	0.16	0.03
DL Methionine	0.14	0.13	0.17
Tallow	2.00	0.07	2.00
Rumensin	0.08	0.05	0.00
Total	100.0	100.0	100.0
Calculated analyses[4]			
CP, %	18.05	14.98	15.49
ME, Kcal/kg	2875	2706	2750
Ca, %	1.00	0.90	3.20
Total P, %	0.70	0.56	0.54
Lysine, %	0.90	0.75	0.75
Methionine, %	0.41	0.35	0.41

[1]Provided choline chloride at a level of 100 mg/kg in the diet

[2]The broiler premix provided the following per kilogram of diet: vitamin A, 10,000 IU; vitamin D3, 2,500 IU; vitamin K, 2.0 mg; panthothenic acid, 14.0 mg; riboflavin, 5.0 mg; folacin, 0.8 mg; niacin, 65.0 mg; thiamine, 2.0 mg; pyridoxine, 4.0 mg; vitamin B12, 0.015 mg; biotin, 0.18 mg; vitamin E, 35 IU; iodine, 0.5 mg; manganese, 70.0 mg; copper, 8.5 mg; zinc, 80.0 mg; selenium, 0.1 mg; iron, 100.0 mg.

[3]The layer premix provided the following per kilogram of diet: vitamin A, 12,000 IU; vitamin D3, 3,000 IU; vitamin K, 2.0 mg; pantothenic acid, 14.0 mg; riboflavin, 6.5 mg; folacin, 1.0 mg; niacin, 40.0 mg; thiamine, 3.3 mg; pyridoxine, 6.0 mg; vitamin B12, 0.02 mg; biotin, 0.20 mg; vitamin E, 40 IU; iodine, 0.5 mg; manganese, 75.0 mg; copper, 15.0 mg; zinc, 80.0 mg; selenium, 0.1 mg; iron, 100.0 mg.

[4]According to NRC (1984) guidelines

Table 3-3. Effect of strain on BW, shank length, liver wt, breast wt, and abdominal fatpad wt at photostimulation (A-Group birds) (Mean±SEM)

				Liver wt		Breast wt[2]		Abdominal fatpad wt	
	n[1]	BW, g	Shank length, mm	g	% BW	g	% BW	g	% BW
Strain									
Exp Line (EL)	20	1867±26*a*	101.7±0.7*a*	31.8±0.8*a*	1.71±0.05*a*	329.7±6.6*a*	17.63±0.18*a*	17.0±2.1*a*	0.90±0.10*a*
Shaver Starbro (SS)	20	1959±26*b*	102.7±0.7*a*	31.1±0.8*a*	1.59±0.05*a*	320.8±6.6*a*	16.37±0.18*b*	16.5±2.1*a*	0.83±0.10*a*

a,b Means within a column with no common alphabetic letter differ significantly (P<0.05)
[1]n=number of birds in each treatment
[2]Breast wt=wt of *Pectoralis major* and *Pectoralis minor*

Table 3-4. Effect of strain on ovary wt and oviduct wt at photostimulation (A-Group birds) (Mean±SEM)

		Ovary wt		Oviduct wt	
	n[1]	g	% BW	g	% BW
Strain					
Exp Line (EL)	20	0.8±0.05*a*	0.040±0.002*a*	0.9±0.2*a*	0.050±0.007*a*
Shaver Starbro (SS)	20	0.9±0.05*a*	0.045±0.002*a*	1.1±0.2*a*	0.054±0.007*a*

a,b Means within a column with no common alphabetic letter differ significantly (P<0.05)
[1]n=number of birds in each treatment

Table 3-5. Effect of strain on carcass composition at photostimulation (A Group birds) (Mean±SEM)

		Water		Protein		Fat		Ash	
	n[1]	g	%BW	g	%BW	g	%BW	g	%BW
Strain									
Exp Line (EL)	20	1267.4±17.7*a*	67.25±0.36*a*	391.4±6.7*a*	20.76±0.22*a*	162.9±7.9*a*	8.65±0.37*a*	64.1±1.3*a*	3.40±0.06*a*
Shaver Starbro (SS)	20	1228.0±17.7*a*	67.71±0.36*a*	373.1±6.7*a*	20.57±0.22*a*	149.9±7.9*a*	8.19±0.37*a*	63.3±1.3*a*	3.49±0.06*a*

a,b Means within a column with no common alphabetic letter differ significantly ($P<0.05$)
[1]n=number of birds in each treatment

Table 3-6. Effects of strain, feeding program and photostimulation program on BW, shank length, liver wt, breast wt, abdominal fatpad wt at sexual maturity (SM) (B-Group birds) (Mean ± SEM)

				Liver wt		Breast wt		Abdominal fatpad wt	
	n[1]	BW, g	Shank length, mm	g	% BW	g	% BW	g	%BW
Main Effects									
Strain									
Exp Line (EL)	39	2709±32*a*	102.3±0.6*a*	47.9±1.1*a*	1.77±0.04*a*	468.2±8.1*a*	17.28±0.18*a*	55.6±2.6*a*	2.05±0.09*a*
Shaver Starbro (SS)	39	2761±32*a*	103.8±0.6*a*	51.3±1.1*b*	1.86±0.04*a*	437.9±8.1*b*	15.83±0.18*b*	54.6±2.6*a*	1.96±0.09*a*
Feeding Program									
Fast Feed (FF)	40	2738±31*a*	102.6±0.6*a*	51.6±1.1*a*	1.89±0.04*a*	448.2±8.0*a*	16.37±0.18*a*	55.7±2.6*a*	2.03±0.09*a*
Slow Feed (SF)	38	2732±32*a*	103.5±0.6*a*	47.7±1.1*b*	1.75±0.04*b*	457.9±8.2*a*	16.74±0.18*a*	54.4±2.7*a*	1.98±0.09*a*
Photostim Program									
Fast Photo (FP)	40	2680±31*a*	102.6±0.6*a*	48.8±1.1*a*	1.82±0.04*a*	442.9±8.0*a*	16.52±0.18*a*	52.2±2.6*a*	1.95±0.09*a*
Slow Photo (SP)	38	2789±32*b*	103.5±0.6*a*	50.4±1.1*a*	1.81±0.04*a*	463.1±8.2*a*	16.59±0.18*a*	57.9±2.7*a*	2.06±0.09*a*
Strain*Feeding Program*Photo Stimulation Program									
EL FF FP	10	2653±63*b*	100.8±1.2*b*	51.4±2.1*ab*	1.93±0.08*a*	454.0±16.1*abc*	17.11±0.35*a*	58.0±5.2*a*	2.19±0.17*a*
EL FF SP	10	2797±63*ab*	102.2±1.2*ab*	50.4±2.1*ab*	1.81±0.08*abc*	471.6±16.1*ab*	16.83±0.35*ab*	57.7±5.2*a*	2.05±0.17*a*
EL SF FP	10	2653±63*b*	103.2±1.2*ab*	43.7±2.1*c*	1.64±0.08*c*	468.0±16.1*ab*	17.60±0.35*a*	50.7±5.2*a*	1.91±0.17*a*
EL SF SP	9	2732±66*ab*	103.1±1.2*ab*	46.3±2.2*b*	1.70±0.08*bc*	479.1±16.9*a*	17.57±0.37*a*	56.1±5.5*a*	2.03±0.18*a*
SS FF FP	10	2766±63*ab*	103.2±1.2*ab*	52.4±2.1*ab*	1.91±0.08*ab*	428.8±16.1*bc*	15.51±0.35*c*	51.6±5.2*a*	1.87±0.17*a*
SS FF SP	10	2734±63*ab*	104.2±1.2*a*	52.0±2.1*ab*	1.90±0.08*ab*	438.3±16.1*abc*	16.03±0.35*bc*	55.7±5.2*a*	2.03±0.17*a*
SS SF FP	10	2648±63*b*	103.0±1.2*ab*	47.8±2.1*abc*	1.81±0.08*abc*	421.0±16.1*c*	15.86±0.35*bc*	48.8±5.2*a*	1.85±0.17*a*
SS SF SP	9	2894±66*a*	104.7±1.2*a*	52.8±2.2*a*	1.83±0.08*abc*	463.5±16.9*abc*	15.92±0.37*bc*	62.3±5.5*a*	2.12±0.18*a*

a-c Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]Breast wt=wt of *Pectoralis major* and *Pectoralis minor*

Table 3-7. Effects of strain, feeding program and photostimulation program on age at sexual maturity (SM), oviduct wt, ovary wt, stroma wt, #SYF, # LYF, % paired LYF at sexual maturity (B-Group birds) (Mean±SEM)

			Oviduct wt		Ovary wt		Stroma wt				
	n[1]	Age at SM, d	g	% BW	g	% BW	g	% BW	#SYF[2]*	#LYF[3]*	% Paired LYF[4]*
Main Effects											
Strain											
Exp. Line (EL)	39	175.2±1.1*a*	60.8±1.4*a*	2.24±0.05*a*	59.9±1.7*a*	1.83±0.06*a*	7.0±0.4*a*	0.26±0.01*a*	10.9±0.8*a*	8.2±0.2*a*	40.13±3.33*a*
Shaver Starbro (SS)	39	177.6±1.1*a*	62.6±1.4*a*	2.28±0.05*a*	59.1±1.7*a*	1.81±0.06*a*	7.9±0.4*a*	0.28±0.01*a*	13.6±0.8*b*	8.1±0.2*a*	44.24±3.38*a*
Feeding Program											
Fast Feed (FF)	40	173.6±1.1*a*	61.4±1.4*a*	2.24±0.05*a*	59.7±1.6*a*	1.82±0.06*a*	7.1±0.4*a*	0.26±0.01*a*	11.6±0.8*a*	8.4±0.2*a*	44.66±3.33*a*
Slow Feed (SF)	38	179.2±1.2*b*	62.0±1.5*a*	2.28±0.05*a*	59.2±1.7*a*	1.81±0.06*a*	7.8±0.4*a*	0.28±0.01*a*	12.9±0.8*a*	8.0±0.2*a*	39.71±3.38*a*
Photostim Program											
Fast Photo (FP)	40	175.3±1.1*a*	58.9±1.4*a*	2.20±0.05*a*	58.4±1.6*a*	1.82±0.06*a*	6.9±0.4*a*	0.26±0.01*a*	12.2±0.8*a*	8.2±0.2*a*	42.41±3.33*a*
Slow Photo (SP)	38	177.4±1.2*a*	64.6±1.5*b*	2.32±0.05*a*	60.5±1.7*a*	1.81±0.06*a*	7.9±0.4*a*	0.28±0.01*a*	12.3±0.8*a*	8.1±0.2*a*	41.96±3.38*a*
Strain*Feeding Program*Photo Stimulation Program											
EL FF FP	10	170.8±2.3*c*	54.4±2.9*b*	2.04±0.10*b*	53.0±3.3*b*	1.63±0.11*b*	5.7±0.7*c*	0.22±0.02*c*	9.8±1.6*b*	7.4±0.4*bc*	28.66±6.58*b*
EL FF SP	10	174.7±2.3*bc*	67.8±2.9*a*	2.42±0.10*a*	64.9±3.3*a*	1.95±0.11*a*	8.6±0.7*ab*	0.31±0.02*ab*	12.2±1.6*ab*	8.7±0.4*a*	46.51±6.58*ab*
EL SF FP	10	177.4±2.3*bc*	60.8±2.9*ab*	2.29±0.10*ab*	64.5±3.3*a*	2.00±0.11*a*	6.7±0.7*bc*	0.25±0.02*abc*	10.0±1.6*b*	8.6±0.4*bc*	45.11±6.58*ab*
EL SF SP	9	177.8±2.4*b*	60.2±3.0*ab*	2.20±0.11*ab*	57.2±3.3*ab*	1.72±0.12*ab*	7.1±0.8*abc*	0.26±0.03*abc*	11.7±1.7*ab*	8.2±0.5*abc*	40.24±6.93*ab*
SS FF FP	10	176.7±2.3*bc*	60.1±2.9*ab*	2.19±0.10*ab*	59.5±3.3*ab*	1.87±0.11*ab*	7.0±0.7*abc*	0.25±0.02*bc*	12.5±1.6*ab*	8.9±0.4*a*	52.90±6.93*a*
SS FF SP	10	172.0±2.3*bc*	63.4±2.9*a*	2.32±0.10*ab*	61.7±3.3*ab*	1.85±0.11*ab*	7.3±0.7*abc*	0.27±0.02*abc*	12.0±1.6*ab*	8.4±0.4*abc*	50.57±6.58*a*
SS SF FP	10	176.3±2.3*bc*	59.9±2.9*ab*	2.27±0.10*ab*	56.8±3.3*ab*	1.78±0.11*ab*	8.4±0.7*ab*	0.32±0.02*a*	16.4±1.6*a*	8.0±0.4*abc*	42.97±6.58*ab*
SS SF SP	9	185.2±2.4*a*	67.1±3.0*a*	2.34±0.11*a*	58.4±3.5*ab*	1.73±0.12*ab*	8.8±0.8*a*	0.30±0.03*ab*	13.3±1.7*ab*	7.2±0.5*c*	30.51±6.93*b*

a-c Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]#SYF=number of small yellow follicles (5-10 mm diameter)

[3]#LYF=number of large yellow follicles (>10 mm diameter)

[4]%Paired LYF=percent of large yellow follicles within 1 g of one another

*Significant pooled Strain*Feeding Program*Photo Stimulation Program interaction (P<0.05)

Table 3-8. Effects of strain, feeding program, and photostimulation program on carcass composition at sexual maturity (SM) (B-Group birds) (Mean±SEM)

		Water		Protein		Fat		Ash	
	n[1]	g	% BW	g	% BW	g	% BW	g	% BW
Main Effects									
Strain									
Exp Line (EL)	39	1698.9±62.2*a*	63.39±0.50*a*	533.6±6.7*a*	20.40±0.26*a*	336.6±10.3*a*	12.82±0.36*a*	88.4±1.5*a*	3.38±0.06*a*
Shaver Starbro (SS)	39	1694.8±62.2*a*	63.60±0.50*a*	544.5±6.7*a*	20.52±0.26*a*	330.2±10.3*a*	12.39±0.36*a*	92.7±1.5*a*	3.50±0.06*a*
Feeding Program									
Fast Feed (FF)	40	1728.2±61.3*a*	63.65±0.49*a*	542.7±6.6*a*	20.47±0.25*a*	331.3±10.1*a*	12.45±0.35*a*	91.0±1.5*a*	3.44±0.06*a*
Slow Feed (SF)	38	1665.5±63.0*a*	63.30±0.50*a*	535.4±6.8*a*	20.45±0.26*a*	335.5±10.4*a*	12.77±0.36*a*	90.1±1.6*a*	3.44±0.06*a*
Photostim Program									
Fast Photo (FP)	40	1673.8±61.3*a*	63.81±0.49*a*	534.6±6.6*a*	20.47±0.25*a*	321.1±10.1*a*	12.28±0.35*a*	89.9±1.5*a*	3.44±0.06*a*
Slow Photo (SP)	38	1719.9±63.0*a*	63.18±0.50*a*	543.5±6.8*a*	20.45±0.26*a*	345.7±10.4*a*	12.93±0.36*a*	91.2±1.6*a*	3.43±0.06*a*
Strain*Feeding Program*Photo Stimulation Program									
EL FF FP	10	1664.8±122.6*a*	63.30±0.98*a*	544.4±13.3*ab*	20.69±0.50*ab*	332.2±20.3*ab*	12.62±0.71*a*	89.3±3.0*ab*	3.40±0.12*ab*
EL FF SP	10	1921.7±122.6*a*	64.58±0.98*a*	536.6±13.3*ab*	19.64±0.50*b*	345.6±20.3*ab*	12.52±0.71*a*	89.1±3.0*ab*	3.27±0.12*b*
EL SF FP	10	1629.2±122.6*a*	63.29±0.98*a*	532.0±13.3*ab*	20.67±0.50*ab*	323.3±20.3*ab*	12.55±0.71*a*	90.1±3.0*ab*	3.50±0.12*ab*
EL SF SP	9	1579.7±129.3*a*	62.41±1.03*a*	521.4±14.0*b*	20.61±0.53*ab*	345.4±21.4*ab*	13.61±0.75*a*	85.1±3.2*b*	3.37±0.13*ab*
SS FF FP	10	1691.6±122.6*a*	63.82±0.98*a*	541.6±13.3*ab*	20.42±0.50*ab*	327.8±20.3*ab*	12.34±0.71*a*	90.3±3.0*ab*	3.41±0.12*ab*
SS FF SP	10	1634.7±122.6*a*	62.91±0.98*a*	548.1±13.3*ab*	21.12±0.50*a*	319.6±20.3*ab*	12.30±0.71*a*	95.3±3.0*a*	3.67±0.12*a*
SS SF FP	10	1709.6±122.6*a*	64.82±0.98*a*	520.4±13.3*b*	20.10±0.50*ab*	301.3±20.3*b*	11.61±0.71*a*	89.7±3.0*ab*	3.47±0.12*ab*
SS SF SP	9	1743.4±129.3*a*	62.83±1.03*a*	567.7±14.0*a*	20.43±0.53*ab*	372.2±21.4*a*	13.31±0.75*a*	95.5±3.2*a*	3.43±0.13*ab*

a,b Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly ($P<0.05$)

[1]n=number of birds in each treatment

3.4 REFERENCES

Association of Official Analytical Chemists. 1980. Official Methods of Analysis, 13th ed AOAC, Washington, DC.

Bornstein, S., Plavnik, I., and Lev, Y. 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci. **25**: 323-341.

Brody, T., Eitan, Y., Soller, M., Nir, I., And Nitsan, Z. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sci. **21**: 437-446.

Feddes, J.J.R., Robinson, F.E., and Lui, C. 1995. Computerized fed portion dispenser for experiments with individually caged birds. Applied Engineering in Agriculture. **11:** 311-314.

Hocking, P.M., Gilbert, A.B., Walker, M., and Waddington, D. 1987. Ovarian follicular structure of White Leghorn fed *ad libitum* and Dwarf and normal broiler breeders fed *ad libitum* or restricted to point of lay. Br. Poult. Sci. **28**: 493-506.

Hocking. P.M., Waddington, D., Walker, M.A., and Gilbert, A.B. 1989. Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. Br. Poult. Sci. **28:** 495-506.

Hocking, P.M. 1993. Effects of body weight at sexual maturity and age of restriction during rearing on the ovarian follicular hierarchy of broiler breeder females. Br. Poult. Sci. **34**: 793-801.

Lupicki, M. 1994. Ovarian morphology and steroidogenesis in domestic fowl (*Gallus domesticus*). Effects of aging, strain, photostimulation program, and level of feeding. M.Sc. Thesis. University of Alberta, Edmonton, AB.

Robinson, F.E., Wilson, J.L., Yu, M.W., Fasenko, G.M., and Hardin, R.T. 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. **72**: 912-922.

Robinson, F.E., Lupicki, M.E., Wautier, T.A., Robinson, N.A., Hardin, R.T., and Wilson, J.L. 1995. Feed and photoperiod management of broiler breeder hens: limiting ovarian development to maximize chick production. Pages 196-205 *in*: Proceedings of the 16th Western Nutrition Conference. September 13/14, 1995, Saskatoon, Saskatchewan.

Sas Institute. 1994. The SAS System for Windows 3.10, Release 6.10. Cary, NC, USA 27513.

Soller, M., Eitan, Y., and Brody, L. 1984. Effect of diet and early quantitative feed restriction on the minimum weight requirement for onset of sexual maturity in White Rock broiler breeders. Poult. Sci. **63**: 1255-1261.

Steel, R.G.D., and Torrie, J.H. 1980. Principles and Procedures of Statistics. 2nd edition. McGraw-Hill Book Co. Inc., New York, NY.

Van Middelkoop, J.H. 1971. Shell abnormalities due to the presence of two eggs in the shell gland. Archiv fur Geflugelkunde **35**: 122-127.

Van Middelkoop, J.H. 1972. The relationship between ovulation interval of White Plymouth Rock pullets and the laying of abnormal eggs. Archiv fur Geflugelkunde **36**: 223-230.

Wilson, J.L, Robinson, F.E., Robinson, N.A., and Hardin, R.T. 1995. Effects of feed allocation on female broiler breeders. J. Appl. Poultry Res. **4**: 193-202.

Yu, M.W., Robinson, F.E., Charles, R., and Weingardt, R. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders. 2. Ovarian morphology and production. Poult. Sci. **71**: 1750-1761.

Yu, M.W., Robinson, F.E., and Robblee, A.R. 1992a. Effect of feed allowance during rearing and breeding on female broiler breeders. 1. Growth and carcass characteristics. Poult. Sci. **71**:1739-1749.

4. EFFECTS OF STRAIN, FEEDING PROGRAM, AND PHOTO STIMULATION PROGRAM ON CARCASS TRAITS, OVARIAN MORPHOLOGY, AND REPRODUCTIVE PERFORMANCE AT 60 WK OF AGE

4.1 INTRODUCTION

Excessive BW in broiler breeder females is negatively correlated with hen-day production, fertility, hatchability, and egg shell quality (Yu *et al*, 1992a, 1992b; Robinson *et al*, 1993). Most commercial broiler breeders are feed restricted during rearing and breeding to limit BW (Summers and Leeson, 1985). It is clear that feed restriction improves reproductive performance by limiting the development of the follicular hierarchy (Hocking *et al*, 1987, 1989; Yu *et al*, 1992a, 1992b, 1992c). This reduction in the number of LYF is associated with a higher rate of lay (Hocking *et al*, 1987; Yu *et al*, 1992b) presumably due to a better control of follicular recruitment and maturation.

Previous research by Robinson *et al* (1995a), with fast and slow feeding programs (differing in the rate of weekly feed allocation increases) and fast and slow photo stimulation programs (differing in the amount of light received each wk) from 20 to 25 wk of age, showed that slow fed birds have a more normal ovary in terms of the LYF hierarchy and laid 10.9 more total eggs than did fast fed birds. It was also found that the slow photoperiod program resulted in a heavier ovary than the fast photoperiod although there were no differences in large yellow follicle numbers.

There is very little information documented on the differences between strains of broiler breeders in terms of ovarian morphology and reproductive performance. As a result of the work by Robinson *et al* (1995a), it was expected that slow fed birds would lay more eggs than fast fed birds. It was also assumed that conventional breeders would have a greater reproductive efficiency than those breeders more highly selected for breast yield. As well, it was hypothesized that slow photoperiod birds would have a greater reproductive efficiency than fast photoperiod birds, since a more gradual photoperiod would mimic natural daylight. The objectives of this experiment were to determine the effects of strain, feeding program, and photo stimulation program on reproductive efficiency, carcass traits, and ovarian morphology to 60 wk of age in broiler breeder pullets.

4.2 MATERIALS AND METHODS

4.2.1 Stocks and Management

Chapter 3 contains a detailed description of the experimental design, stocks, rearing, rations, housing facilities, and the experimental treatments. Briefly, 400 birds each of two strains -Shaver Starbro (SS) and a Shaver Experimental Line (EL) - were reared in floor pens until 20 wks of age following Shaver breeder management guidelines for target BW and feed allocations. At 20 wks of age, the 204 birds of each strain closest to the target BW were individually caged (0.19 m^2) and were randomly assigned to one of two feeding programs, Fast Feed (FF) or Slow Feed (SF), and to one of two photo stimulation programs, Fast Photoperiod (FP) or Slow Photoperiod (SP). Birds were then randomly assigned to one of three groups. A-Group birds (20 birds of each strain) were processed at photo stimulation. B-Group consisted of 10 birds per strain*feeding program*photo stimulation program interaction and these birds were processed at sexual maturity. The final group, the C-Group birds were maintained for production records and were processed at 60 wk of age. The results of these birds are reported in this paper. C-Group birds consisted of 36 birds per interaction. Each interaction of 36 birds was divided into two lots of 18 birds each for a total of 16 lots. Every bird was individually weighed at weekly intervals in order to derive feed allocations for the week. Feed allocations were based on weekly BW measurements until sexual maturity, after which time allocations were then based on BW as well as weekly egg production. Feed allocations for the breeding period are shown in Table 4-1.

A total of 34 C-Group birds were not included in the egg production data set because they either died or were culled. Birds died or were culled due to following: oviductal prolapse (n=2), skeletal disorders (n=7), aortic rupture (n=1), sudden death syndrome (n=2), cystic oviduct (n=2), ruptured liver (n=3), haemorrhaged liver (n=1), fatty liver syndrome (n=1), peritonitis (n=5), arthritis (n=1), and tendonitis (n=1). There were six birds of which no lesions were visible and two birds that were not suitable for *post mortem* dissection as they were decomposed. A total of 254 were included in the egg production data set as well as the 60 wk processing data set.

4.2.2 *Egg Production Records*

Age at first oviposition was used to assess sexual maturity. Each bird, as well as her egg, were weighed at the time of sexual maturity. Every egg was recorded daily for production records using the following letter designations:

A=normal, hard-shelled

B=soft-shelled

C=shelless

D=double yolk

E=broken

F=abnormal shell

G=pecked

in order to facilitate determination of laying sequences. The prime laying period during which most eggs were collected was considered to be between 0700 and 1500h (Etches, 1990). Each egg from each hen was weighed daily until two consecutive eggs of a minimum of 52 g were obtained, denoting suitable settable egg weight. Once the settable egg age had been achieved, only one normal egg from each hen was weighed per wk on a predetermined day. If no egg was present, then the next egg was weighed. The egg weights were then averaged on a monthly basis.

Sequence analysis was applied to the production data with a sequence being defined as the number of days of consecutive ovipositions that are separated by one or more pause days. Prime sequence length was also recorded. The prime sequence can be defined as the longest sequence, or "clutch", of eggs laid by a hen, and it usually occurs around the time of peak production. Once all the egg data was entered into the computer, a sequence analyser computer program was used to compute average and prime sequence lengths as well as pause lengths (Martin Zuidhof, Agriculture, Food, and Rural Development, Edmonton, Alberta, Canada, T6H 5T6, personal communication).

4.2.3 *Fertility and Hatchability*

Beginning at 26 wk of age, each hen was artificially inseminated weekly with 50 μL of fresh pooled

undiluted semen collected by abdominal massage from caged broiler breeder males that were the same age as the females. The 36 hens within each treatment were assigned to groups (lots) for a total of 16 lots. Eggs were collected and sorted by lot daily. Eggs collected over 7 d periods from 27 wk to 60 wk were incubated for 21 d at a commercial hatchery (Lilydale Co-operative Ltd., Edmonton, AB, Canada T5C 1R9). Unhatched eggs were broken open and assessed macroscopically for fertility status and stage of embryonic development. Scores for each egg were as follows: clear (assumed infertile), embryonic death occurring during stage 1 of development (0-7 d of incubation), stage 2 of development (8-14 d of incubation), stage 3 of development (after 14 d of incubation), dead in shell, or cull chick. Very early dead and infertile eggs can be misclassified using this procedure because of breakdown of yolk (Katanbaf *et al*, 1989). Percentage fertility and hatchability were determined on a lot basis. Fertility was calculated as the number of fertile eggs divided by the number of eggs set. Hatchability was defined as the number if viable chicks obtained from the total number of eggs set. Hatchability of fertile eggs set was defined as the number of viable chicks hatched divided by the number of fertile eggs set.

4.2.4 Bird Processing at 60 wk of Age

At 60 wk of age, the remaining 254 C-Group birds were euthanised and processed similar to the methods discussed in Chapter 3. Briefly, carcass wt and shank length were recorded prior to dissection of the birds. The breast muscle, liver, fat pad (including fat adhering to the gizzard), ovary oviduct, number of LYF, number of SYF, and stroma wt were recorded. Chemical analysis was not done on the C-Group birds. At this time, any reproductive problems that were present were observed and recorded. These included such phenomena as internal ovulation, internal laying, atresia, ovarian regression, and cystic right oviducts.

4.2.5 Statistical Analysis

Data were subject to a three-way Analysis of Variance for the main effects of strain (d.f.=1), feeding program (d.f.=1), and photo stimulation program (d.f.=1) and the pooled strain*feeding program, strain*photo stimulation program, feeding program*photo stimulation program, and strain*feeding program*photo stimulation interactions (d.f.=4) program using the General Linear Models Procedure of SAS (SAS Institute,

1994). The significant differences among the strain*feeding program*photo stimulation program means were determined using the Least Significant Difference t-test (Steel and Torrie, 1980) and are based on $P \leq 0.05$, unless otherwise stated. Pearson correlation coefficients of the interrelationships among traits were computed for both the A-Group and B-Group birds. The experiment proposal was reviewed and approved by the Faculty Animal Policy and Welfare Committee of the Faculty of Agriculture, Forestry, and Home Economics of the University of Alberta.

4.3 RESULTS AND DISCUSSION

4.3.1 Growth and Sexual Maturity

Actual body wt curves are shown for the main effects of strain (Figure 4-1), feeding program (Figure 4-2), and photo stimulation program (Figure 4-3). Body wt did not differ between strain throughout the entire experiment. It was expected that the EL would have a greater BW as it has been selected for higher breast yield, and hence, greater BW. Since both strains were managed according to Shaver Starbro management guidelines, perhaps the EL did not receive as many nutrients as it requires to achieve maximum breast muscle yield and therefore, large differences in BW were not observed between the strains. From 21 to 28 wk of age, SF birds were consistently lower in BW than FF birds. This would be expected from 21 to 25 wks of age as this was the period in which the feeding programs were implemented. It is possible that the SF program was too conservative and the birds required three more wks to "catch up" to the same target wt as the FF birds. Body weights were essentially the same for both photo stimulation programs each week.

Table 4-2 displays production parameters associated with sexual maturity for the C-Group birds. Fast fed birds reached settable egg age (two consecutive eggs weighing 52 g) 2 d before SF birds. The only main effect that BW at sexual maturity was found to be significantly different for was feeding program, with the FF birds being heavier (2781 g) than SF birds (2617 g). Body weight at sexual maturity for strain, photo stimulation program, and the strain*feeding program*photo stimulation program interaction was not different. The age at sexual maturity for the C-Group birds was not different for strain with EL birds reaching sexual maturity at 175.0 d whereas the SS birds attained sexual maturity at 176.0 d. Age at sexual maturity was also not significantly different for the C-Group birds for feeding program (FF: 174.6 d, SF: 176.3 d), but

it was significantly different for the B-Group birds with FF birds reaching sexual maturity (173.6 d) before SF birds (179.2 d). Photo stimulation program also did not have any differences for age at sexual maturity (FP 176.0 d, SP: 175.0 d). Age at sexual maturity was correlated with settable egg age (r=0.563) and with days from photo stimulation to settable egg age (r=0.563). As well, settable egg age was found to be positively correlated with days from photo stimulation to sexual maturity (r=0.563) as well as with days from sexual maturity to the occurrence of a settable egg (r=0.405). These correlations are supported by Goerzen (1996), who also observed that age at sexual maturity was positively correlated with settable egg age (r=0.440) and with days from photo stimulation to settable egg age (r=0.550). While strain and photo stimulation did not have any effects on traits associated with sexual maturity, feeding program did have a significant effect on several of the parameters. Days from photo stimulation to sexual maturity did not differ for the main effects or the interactions with the average being about 28 d. First egg weight was found to be significantly different only for the main effect of feeding program; fast fed birds laid a heavier first egg (46.2 g) than did the SF birds (44.6 g). There were no differences between the strains for the age at which a settable egg was laid. Slow fed birds were 2 d older than FF birds when they reached settable egg age. There were also no differences for photo stimulation program, but the treatment combinations with SF reached a settable egg age later than the other treatment combinations. As with the parameter settable egg age, days from photo stimulation to settable egg was significantly later in SF birds (2 d) than FF birds. Days from sexual maturity to settable egg age did not differ for the main effects or for the strain*feeding program*photo stimulation program interaction.

4.3.2 Egg Production

Broiler breeder hens generally achieve lower peak rates of lay and exhibit poorer persistency of lay when compared to egg-type hens. Figures 4-4, 4-5, and 4-6 display the weekly % hen day production for strain, feeding program, and photo stimulation program, respectively, for the duration of the breeding period. Egg production rate is reduced as hens age (Bahr and Palmer, 1989). Age-related declines in egg production could be due to a number of factors; an increased incidence of follicular atresia (Williams and Sharp, 1978a; Waddington *et al.* 1985), a reduction in the rate of follicular maturation (Johnson *et al.* 1986; Hocking *et al.*

!987), and decreases in responses to hormonal feedbacks (Williams and Sharp, 1978b) appear to be the most common factors affecting egg production as the hen ages. This decline in egg production as hens age is evident when examining the % hen day production curves. The shape, peak production, and persistency of lay were quite similar for the three main effects. Peak production (calculated on a weekly basis) for each of the main effects occurred at 29 wk of age. Peak production was 89 % for EL birds and 86 % for SS birds. Egg production was maintained between 80 and 85 % until 35 wk of age, after which, it declined in a relatively uniform manner to 56 % for EL birds and 60 % for SS birds at 60 wk of age. Peak production was 87 % for both feeding programs. As with strain, production was maintained between 80 % and 85 % up until 35 wk of age and then declined to 57 % for FF birds and 59 % for SF birds to 60 wk of age. Peak production for both photo stimulation programs was 87 %. Egg production declined to 60 % for FP birds and 56 % for SP birds at the end of lay.

Total egg production, settable egg production, and the amount of eggs from each of the different egg classes are recorded in Table 4-4. Total egg production did not differ for the main effect of strain with the EL birds laying a total of 169.0 eggs and the SS birds 170.7 eggs. Total egg production also was not significantly different for photo stimulation program with 169.9 eggs for FP birds and 169.8 eggs for SP birds. Although not significantly different, there was a numerical difference (P=0.082) in total egg production between the feeding programs. Slow fed birds had a 6.0 egg advantage over FF birds. Robinson *et al* (1995a) reported similar results with a significant difference of 10.9 eggs more for SF birds. With the slow feeding program, there appears to be better control of the ovary in terms of follicular recruitment and maturation, hence fewer double hierarchies and more total eggs. At sexual maturity (B-Group birds) it was observed that SF birds had numerically lower % paired LYF (39.71 %) than FF birds (44.66 %). Settable egg production was also numerically higher (P=0.06) for SF birds than SS birds, while it was not different for strain, photo stimulation program, or the interactions. Shaver Starbro birds were not reproductively superior to the EL birds, as was expected. There are two explanations for this. The first being that when birds were selected for the trial, it was the birds that were closest to target BW meaning excessively heavy or light birds were not included, which would greatly affect results. Problems seen with excessively heavy birds (ie. *ad libitum* fed), include follicular atresia, internal ovulation, internal laying, the production of soft-shelled or membranous eggs, the

production of multiple-yolked eggs, or combinations of the above (Jaap and Muir, 1968; van Middelkoop, 1971, 1972). Secondly, because both strains were managed according to Shaver Starbro management guidelines for BW and feed allocations, the EL may not have been able to put as many nutrients toward lean muscle mass, specifically breast muscle mass, resulting in greater BW, and hence, reproductive efficiency was better than expected. Slow fed birds were superior to FF birds in terms of the number total eggs and settable eggs laid.

The only egg class in which there was a significant difference for a main effect was the amount of double-yolked egg that were laid. Both on a total number basis as well as a percent of total egg production, the FF birds laid more double yolk eggs (0.40 %) than SF birds (0.23 %). Robinson *et al* (1995a) also observed this. There were no differences in the number of soft-shelled, shelless, or abnormal shelled eggs for any of the main effects or for interactions. The incidence of abnormal eggs is negatively correlated with the production of settable eggs, and, hence viable embryos. Abnormal shelled eggs, shelless eggs, and soft-shelled eggs were all found to be lowly negatively correlated with settable egg production, r=-0.134, =-0.169, and r=-0.235, respectively. The condition known as erratic oviposition defective egg syndrome (EODES) described by Jaap and Muir (1968) and van Middelkoop (1971, 1972) is evident upon observing abnormal eggs such as soft-shelled, membranous, and multiple-yolked. Though this condition is more prevalent in *ad libitum* fed broiler breeders, it appears that small differences in feed allocation in the early laying period result in a mild case of EODES.

Most hens lay short sequences of 6 to 10 eggs shortly after the onset of production. About 6 to 8 wk after that time, most hens lay a very long sequence of eggs (Robinson *et al*, 1990). "Prime sequence" is the term commonly used to refer to this characteristically long sequence seen at peak production. For all three main effects, the weekly sequence length curves were similar in that shorter sequences were laid during the early laying period, a peak value was reached, and then the sequence lengths decreased markedly with age. Experimental Line birds had longer average weekly sequence lengths than SS birds up until 52 wk of age after which time they were not different (Figure 4-7). Sequence lengths were low at the onset of production and reached a peak value of 13.8 d for EL birds and 10.8 d for SS birds and then declined to 1.9 d for EL birds and 2.0 d for SS birds at 60 wk of age. The SF hens exhibited sequences of longer duration than FF

hens from 26 to 40 wk of age (Figure 4-8). At the end of lay, sequence length for FF birds was 2.1 d and for SF birds, it was 1.9 d. The peak value was reached at 29 wk and was 10.7 d for FF birds and 14.0 d for SF birds. Average weekly sequence lengths were fairly consistent between the photo stimulation programs (Figure 4-9) with the peak being 12.2 d for FP birds and 12.4 d for SP birds, occurring at 29 wk of age, declining to 2.1 d for FP birds and 1.8 d for SP birds at 60 wk of age. The shape of the sequence length curves (Figures 4-7, 4-8, and 4-9) resembled the shape of the % hen day production curves (Figures 4-4, 4-5, and 4-6) in the sense that the longest sequences occurred approximately at the same time as peak production.

Overall, all birds appeared to have relatively the same number of ovulations, sequences, and pauses (Table 4-3). The average sequence length for the main effects and interaction was around 3.2 d, while the average pause length was found to be 1.3 d. The EL birds had a significant 3.9 egg longer prime sequence than SS birds (Table 4-3). Slow fed birds had a longer prime sequence than FF birds, 17.5 eggs and 14.4 eggs, respectively (Table 4-3). Experimental Line birds and slow fed birds may have better control of the ovary in terms of recruitment and maturation of LYF resulting in the laying of one egg every 24 h period resulting in a longer prime sequence length. Photo stimulation program had no effect on prime sequence length, however, there was a significant difference for prime sequence length among the treatment combinations with the treatment combinations consisting of EL birds having a consistently longer prime sequence than those treatment combinations with SS birds (Table 4-3). The shortest prime sequence was observed for the SS*SF*SP treatment combination (11.3 d) while the longest prime sequence was observed in the EL*SF*SP treatment combination (22.6 d). Prime sequence length was positively correlated to total egg production (r=0.541) and to settable egg production (r=0.535). Goerzen (1996) also reported a positive correlation between prime sequence length and total eggs (r=0.485) and settable eggs (r=0.478) and Robinson *et al* (1990) reported a positive correlation between prime sequence length and total eggs (r=0.399).

4.3.3 Egg Weights

The weight of the first egg was not different between strain, but the FF birds laid a significantly larger first egg than SF birds. It was also not different for photo stimulation program or for the strain*feeding

program*photo stimulation program interaction. Monthly average egg wts are presented in Table 4-5. There were significant differences in egg wt between strain and feeding program the first three months with SS and FF birds having greater egg wts than EL and SF birds. For the remainder of the months, wts are similar for the strains. Although not significantly different, there were numerical differences in egg wts with the wts being consistently greater for FF birds than for SF birds and greater for SP birds than FP birds. There was a trend that can be observed in terms of egg wt and increasing age in that egg wts were greater for each successive month, as the hens aged. The observation of average egg wt increasing over time is consistent with previous studies (O'Sullivan, 1991). As the hen ages, she produces fewer, but larger eggs. With age, yellow yolk is deposited in fewer follicles which reach a larger size; the rate of transport of yellow yolk into follicles increases which results in the production of larger eggs (Bahr and Palmer, 1989).

4.3.4 Fertility, Hatchability, and Incubation Traits

Fertility, hatchability, and incubation traits are tabulated in Table 4-6. As well, fertility and hatchability were summarized on a monthly basis for each of the main effects and are presented in Figures 4-10 through to 4-15. Overall fertility did not differ between the strains, but there was a numerical difference in monthly fertility (Figure 4-10) with the SS hens having slightly higher fertility up until the last month. Fertility did not differ for feeding program, both overall or an a monthly basis although FF birds had a numerically higher fertility in the earlier months while SF birds had higher fertility in the latter months. Photo stimulation program also did not experience any differences in fertility with monthly fertility being numerically higher in SP birds. Fertility of the EL*FF*FP treatment combination was found to be significantly lower than any of the other interactions. Reasons for this are unknown. It is not surprising that fertility did not decline with time, as each bird was artificially inseminated weekly which would basically cancel out factors which cause fertility to decline with time in naturally mating flocks.

Both overall and monthly hatchability did not differ for strain, but SS hens had slightly better hatchability than EL hens upon examining the monthly hatchability. There were also no differences observed for overall hatchability for the main effects of feeding program and photo stimulation program, while monthly hatchability was numerically greater for SF birds and for SP birds. Again, the EL*FF*FP treatment

combination had a lower value for hatchability than the other interactions. There were no observed differences for the main effects for hatch of fertile eggs set.

Mortality at different stages of incubation, the incidence of chicks dead in the shell, as well as cull chicks were recorded from the eggs that did not hatch (Table 4-6). Unlike Robinson *et al* (1995a), who found greater mortality at stages 1 and 2 for FF birds, stage 1 (mortality during 0-7 d of incubation), Stage 2 (mortality during 8-14 d of incubation), and Stage 3 (mortality after 14 d of incubation) did not have any significant differences for the main effects or for the strain*feeding program*photo stimulation program interaction. The percentage of chicks found dead in the shell was also not significantly different for the any main effect or for the strain*feeding program*photo stimulation program interaction. The percentage of cull chicks of total eggs set was not different strain, feeding program, or photo stimulation program, but it was different for the strain*feeding program*photo stimulation program interaction.

4.3.5 Carcass Traits at 60 wk of Age

Table 4-7 displays BW, shank length, liver wt, breast wt, and abdominal fatpad wt at 60 wks of age. At the end of lay, there were no differences in BW for the main effects or for the strain*feeding program*photo stimulation program interaction. Shank length was greater for the SS birds than the EL birds both at 21 wk of age and at the 60 wk processing. This implies that even at 21 wk of age, the commercial strain has a greater frame size and this size is maintained throughout the life of the bird. Absolute liver wt at the end of lay, was significantly heavier for SS bird than EL birds and also for SF birds than FF birds, which could be related to the rate of lay at this time. Slow fed birds also had a heavier liver wt than FF birds as a % of BW. There were no differences for liver wt for photo stimulation program or the strain*feeding program*photo stimulation program interaction.

The differences between breast muscle wt at sexual maturity were also evident at the end of the trial. Experimental Line birds still had a greater absolute breast wt (604.0 g) than the SS birds (548.7 g) as well as a greater breast wt expressed as a % of BW (16.43 %) when compared to SS birds (14.93 %). There were no differences in breast wt as an absolute value or a s a % of BW for the main effects of feeding program and photo stimulation program. Although there were no significant differences for breast wt for the

strain*feeding program*photo stimulation program interaction, there were numerical differences with the treatment combinations consisting of EL birds having greater breast wts. As found at sexual maturity, breast wt was found to be highly positively correlated with BW (r=0.686).

Abdominal fat pad was not different for the main effects or the strain*feeding program*photo stimulation program interaction at the end of lay. There was a positive correlation between fat pad wt and BW (r=0.618).

Reproductive traits (oviduct wt, ovary wt, stroma wt, number of SYF, and number of LYF) are tabulated in Table 4-8. Neither absolute oviduct wt nor oviduct wt as a % of BW were different for any of the main effects, but there were differences for the strain*feeding program*photo stimulation program interaction for both. The main effects and the strain*feeding program*photo stimulation program interaction did not have any effects on ovary wt at the end of lay. Hocking *et al* (1987) found that follicle number declines with age due to reduced follicular recruitment and maturation. The ovary represents a smaller proportion of BW at 60 wk of age than at sexual maturity (B-Group birds) which is reflected in the number of LYF with more LYF present at sexual maturity than at 60 wk of age. The average number of LYF at sexual maturity was 8.0 while the average number at 60 wks of age was 4.0. The number of LYF observed here at the end of lay is consistent with values reported by others (Yu *et al.* 1992b; Robinson *et al.* 1995b; Goerzen, 1996). There was a difference in SYF numbers for strain at the end of lay with EL birds having more SYF (16.5) than SS birds (14.5). The reason for these numbers being different is not known.

Reproductive anomalies were observed at the time of processing. Of the 254 birds that were processed, the incidence of atresia was 9.06% (n=23), ovarian regression was 2.76% (n=7), right cystic oviduct was 19.69 % (n=50), internal ovulation was 6.30 % (n=16), and internal laying was 2.76 % (n=7).

Overall, there were very few strain differences in terms of reproductive characteristics. It was hypothesized that the conventional strain (Shaver Starbro) would be reproductively superior to the strain more highly selected for breast yield. This is not what was observed. Since the Experimental Line was selected for greater breast yield, we would expect a heavier BW, and hence poorer reproductive efficiency as a result of the negative relationship that exists between BW and reproductive efficiency. The Experimental Line birds did not attain as great a weight as they possibly could have and this was reflected in the egg

production records. Both strains had relatively the same numbers for total and settable egg production, but the Experimental Line had a longer prime sequence than the Starbro, which is an important parameter when considering persistency of lay. The longer prime sequence for the EL birds suggests that these birds may have a better control over the ovary in terms of follicular recruitment and maturation.

In this trial, feeding program had the most impact on the traits measured. In general, a slow feeding program would be the one of choice in terms of improving total egg production as well as parameters associated with production. Although not significantly different, there was a numerical difference between the feeding programs for total and settable eggs with both being greater for the SF birds. Slow fed birds also had a longer prime sequence than FF birds. As with the EL birds, we can only assume that the SF birds have a better control over the ovary resulting in fewer abnormal eggs as a result of multiple ovulations. The SF birds had fewer abnormal eggs such as double-yolked eggs than did the FF birds. Some incidences of double-yolked eggs are expected, but in terms of reproductive efficiency, it is unacceptable, as the goal of broiler breeder management is to achieve the greatest settable egg production possible.

In terms of photo stimulation program, there were very few differences. It was hypothesized that the SP birds would have a better reproductive efficiency than FP birds as the slow photoperiod would more closely mimic natural daylight conditions. In terms of egg production, there were no differences between the two photo stimulation programs. What appears to be important is that the birds receive increasing day length, but the rate of increase does not seem to be a major factor in affecting reproductive efficiency in broiler breeders.

It appears that the reproductive success of any bird comes down to a fine-tuned management protocol taking into effect not only requirements of individual birds, but also differences in genetics.

Table 4-1. Daily feed allowances of feeding program (fast or slow) from 21 to 60 wk. of age for all birds individually caged (g/bird/d)

	Feeding Program	
Age (wk)	Fast Feed (FF)	Slow Feed (SF)
21 to 22	125	100
22 to 23	130	105
23 to 24	130	113
24 to 25	130	119
25 to 26	130	128
26 to 27	130	137
27 to 28	140	140
28 to 29	142	148
29 to 30	143	153
30 to 31	147	158
31 to 32	150	158
32 to 33	152	158
33 to 34	152	158
34 to 35	150	156
35 to 36	148	154
36 to 37	145	151
37 to 38	144	150
38 to 39	141	147
39 to 40	139	145
40 to 41	139	144
41 to 42	138	143
42 to 43	138	143
43 to 44	138	143
44 to 45	136	141
45 to 46	136	141
46 to 47	134	138
47 to 48	134	138
48 to 49	133	137
49 to 50	131	136
50 to 51	131	135
51 to 52	130	134
52 to 53	130	133
53 to 54	129	133
54 to 55	129	133
55 to 56	125	129
56 to 57	125	129
57 to 58	125	129
58 to 59	125	129
59 to 60	125	129

Table 4-2. Effects of strain, feeding program, and photostimulation program on production parameters associated with sexual maturity (C-group birds) (mean±SEM)

	n[1]	BW at SM, g	Age at SM, d	Days from PS[2] to SM[3], d	First egg wt, g	Settable egg age[4]*, d	Days from PS to settable egg*, d	Days from SM to settable egg, d
Main Effects								
Strain								
Exp Line (EL)	10	2725±27*a*	175.0±0.7*a*	28.0±0.7*a*	45.2±0.5*a*	184.5±0.5*a*	37.5±0.5*a*	9.6±0.5*a*
Shaver Starbro (SS)	10	2673±28*a*	176.0±0.7*a*	29.0±0.7*a*	45.6±0.5*a*	185.5±0.5*a*	38.5±0.5*a*	10.7±0.5*a*
Feeding Program								
Fast Feed (FF)	10	2781±28*a*	174.6±0.7*a*	27.6±0.7*a*	46.2±0.5*a*	184.1±0.5*a*	37.1±0.5*a*	10.2±0.5*a*
Slow Feed (SF)	10	2617±28*b*	176.3±0.7*a*	29.3±0.7*a*	44.6±0.5*b*	186.0±0.5*b*	39.0±0.5*b*	10.1±0.5*a*
Photostim Program								
Fast Photo (FP)	10	2681±27*a*	176.0±0.7*a*	29.0±0.7*a*	45.7±0.5*a*	185.4±0.5*a*	38.4±0.5*a*	10.5±0.5*a*
Slow Photo (SP)	10	2717±28*a*	175.0±0.6*a*	28.0±0.7*a*	45.1±0.5*a*	184.7±0.5*a*	37.7±0.5*a*	9.8±0.5*a*
Strain*Feeding Program*Photo Stimulation Program								
EL FF FP	10	2820±54*a*	175.9±1.3*a*	28.9±1.3*a*	46.2±1.0*a*	183.6±1.0*b*	36.6±1.0*bc*	9.3±1.1*a*
EL FF SP	10	2791±56*ab*	174.1±1.3*a*	27.1±1.3*a*	45.8±1.0*a*	184.3±1.0*bc*	37.3±1.0*bc*	10.2±1.0*a*
EL SF FP	10	2669±53*bcd*	176.0±1.3*a*	29.0±1.3*a*	44.7±1.0*a*	187.3±1.1*a*	40.3±1.1*a*	10.7±1.1*a*
EL SF SP	10	2618±54*cd*	174.2±1.3*a*	27.2±1.3*a*	43.9±1.0*a*	182.9±1.1*c*	35.9±1.1*c*	8.2±1.1*a*
SS FF FP	10	2715±56*abc*	174.3±1.3*a*	27.3±1.3*a*	46.6±1.0*a*	183.2±1.0*c*	36.2±1.0*c*	10.9±1.0*a*
SS FF SP	10	2798±54*ab*	174.3±1.3*a*	27.3±1.3*a*	46.3±1.0*a*	185.1±1.0*abc*	38.1±1.0*abc*	10.4±1.0*a*
SS SF FP	10	2518±55*d*	177.7±1.3*a*	30.7±1.3*a*	45.3±1.0*a*	187.3±1.0*a*	40.3±1.0*a*	11.1±1.0*a*
SS SF SP	10	2661±57*bcd*	177.6±1.4*a*	30.6±1.4*a*	44.4±1.0*a*	186.5±1.1*ab*	39.5±1.1*ab*	10.3±1.0*a*

a-d Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly ($P<0.05$)

n[1]=number of birds in each treatment

PS[2]=photostimulation

SM[3]=sexual maturity

Settable egg age[4]=hen age at second consecutive egg weighing over 52 g

*Significant pooled Strain*Feeding Program*Photo Stimulation Program interaction ($P<0.05$)

Table 4-3. Effects of strain, feeding program and photostimulation program on number of ovulations, sequence data, and pause data (C-Group birds) (Mean ± SEM)

	n[1]	# of ovulations	# of sequences	Avg sequence length	Prime sequence length*	# of pauses	Avg pause length
Main Effects							
Strain							
Exp Line (EL)	130	176.1±2.2*a*	56.0±1.1*a*	3.3±0.1*a*	17.9±1.0*a*	55.1±1.1*a*	1.31±0.04*a*
Shaver Starbro (SS)	124	176.9±2.3*a*	58.0±1.1*a*	3.2±0.1*a*	14.0±1.0*b*	57.0±1.1*a*	1.29±0.04*a*
Feeding Program							
Fast Feed (FF)	128	173.8±2.3*a*	57.5±1.1*a*	3.2±0.1*a*	14.4±1.0*a*	56.6±1.1*a*	1.35±0.04*a*
Slow Feed (SF)	126	179.1±2.3*a*	56.5±1.1*a*	3.3±0.1*a*	17.5±1.0*b*	55.6±1.1*a*	1.25±0.04*a*
Photostim Program							
Fast Photo (FP)	128	176.8±2.3*a*	55.5±1.1*a*	3.3±0.1*a*	16.2±1.0*a*	54.5±1.1*a*	1.32±0.04*a*
Slow Photo (SP)	126	176.2±2.3*a*	58.5±1.1*a*	3.1±0.1*a*	15.6±1.0*a*	57.7±1.1*b*	1.28±0.04*a*
Strain*Feeding Program*Photo Stimulation Program							
EL FF FP	32	166.4±4.5*b*	55.6±2.2*ab*	3.1±0.2*ab*	14.1±2.0*bcd*	54.6±2.2*ab*	1.44±0.08*a*
EL FF SP	32	174.1±4.5*ab*	59.7±2.2*a*	3.1±0.2*ab*	16.0±2.0*bcd*	59.0±2.2*a*	1.29±0.08*ab*
EL SF FP	32	181.0±4.5*a*	53.2±2.2*b*	3.6±0.2*a*	18.9±2.0*ab*	52.2±2.2*b*	1.28±0.08*ab*
EL SF SP	34	182.7±4.4*a*	55.7±2.2*ab*	3.4±0.2*a*	22.6±2.0*a*	54.7±2.2*ab*	1.24±0.08*ab*
SS FF FP	31	177.1±4.6*ab*	56.7±2.2*ab*	3.3±0.2*ab*	14.5±2.0*bcd*	55.7±2.2*ab*	1.41±0.08*a*
SS FF SP	31	177.7±4.6*ab*	58.0±2.2*ab*	3.1±0.2*ab*	13.0±2.0*cd*	57.0±2.2*ab*	1.26±0.08*ab*
SS SF FP	33	182.8±4.5*a*	56.4±2.2*ab*	3.4±0.2*ab*	17.4±2.0*abc*	55.4±2.2*ab*	1.17±0.08*ab*
SS SF SP	29	170.1±4.8*ab*	60.7±2.2*a*	2.8±0.2*b*	11.3±2.0*d*	60.0±2.3*a*	1.31±0.08*a*

a-d Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

*Significant pooled Strain*Feeding Program*Photo Stimulation Program (P<0.05)

Table 4-4. Effects of strain, feeding program and photostimulation program on parameters associated with egg production to 60 wk of age (C-Group birds) (Mean ± SEM)

			Settable Eggs[2]		Soft shell Eggs		Shelless Eggs		Double yolk Eggs		Abnormal Eggs	
	n[1]	Total Eggs	Total*	%[3]	Total	%[3]	Total	%[3]	Total	%[3]	Total	%[3]
Main Effects												
Strain												
Exp Line (EL)	130	175.4±2.2*a*	169.0±2.3*a*	96.2±0.4*a*	3.8±0.5*a*	2.20±0.30*a*	1.4±0.2*a*	0.79±0.12*a*	0.6±0.1*a*	0.36±0.05*a*	0.7±0.2*a*	0.42±0.11*a*
Shaver Starbro (SS)	124	176.9±2.3*a*	170.7±2.3*a*	96.8±0.4*a*	3.0±0.5*a*	1.68±0.30*a*	1.3±0.2*a*	0.76±0.12*a*	0.5±0.1*a*	0.27±0.05*a*	0.9±0.2*a*	0.50±0.11*a*
Feeding Program												
Fast Feed (FF)	128	173.1±2.3*a*	166.8±2.3*a*	96.3±0.4*a*	3.4±0.5*a*	1.97±0.30*a*	1.6±0.2*a*	0.93±0.12*a*	0.7±0.1*a*	0.40±0.05*a*	0.6±0.2*a*	0.40±0.11*a*
Slow Feed (SF)	126	178.2±2.2*a*	172.9±2.3*a*	96.7±0.4*a*	3.3±0.5*a*	1.91±0.30*a*	1.1±0.2*a*	0.61±0.12*a*	0.4±0.1*b*	0.23±0.05*b*	1.0±0.2*a*	0.52±0.11*a*
Photostim Program												
Fast Photo (FP)	128	176.2±2.3*a*	169.9±2.3*a*	96.4±0.4*a*	3.4±0.5*a*	1.96±0.30*a*	1.4±0.2*a*	0.81±0.12*a*	0.6±0.1*a*	0.35±0.05*a*	0.8±0.2*a*	0.48±0.11*a*
Slow Photo (SP)	126	175.7±2.3*a*	169.8±2.3*a*	96.6±0.4*a*	3.3±0.5*a*	1.92±0.30*a*	1.3±0.2*a*	0.74±0.12*a*	0.5±0.1*a*	0.28±0.05*a*	0.8±0.2*a*	0.44±0.11*a*
Strain*Feeding Program*Photo Stimulation Program												
EL FF FP	32	165.8±4.5*b*	156.3±4.6*c*	94.3±0.8*b*	5.3±1.0*a*	3.19±0.60*a*	2.1±0.4*a*	1.28±0.23*a*	0.8±0.2*a*	0.44±0.09*a*	1.2±0.4*a*	0.77±0.22*a*
EL FF SP	32	173.3±4.5*ab*	167.6±4.6*abc*	96.7±0.8*a*	3.1±1.0*ab*	1.83±0.60*ab*	1.5±0.4*ab*	0.82±0.23*ab*	0.8±0.2*a*	0.43±0.09*a*	0.3±0.4*a*	0.21±0.22*a*
EL SF FP	32	180.5±4.5*a*	176.1±4.6*a*	97.6±0.8*a*	2.6±1.0*ab*	1.43±0.60*b*	0.8±0.4*b*	0.44±0.23*b*	0.6±0.2*ab*	0.32±0.09*ab*	0.4±0.4*a*	0.22±0.22*a*
EL SF SP	34	182.2±4.4*a*	175.9±4.4*a*	96.3±0.8*ab*	4.0±1.0*ab*	2.36±0.60*ab*	1.1±0.4*ab*	0.61±0.23*b*	0.4±0.2*ab*	0.23±0.09*ab*	0.8±0.4*a*	0.47±0.22*a*
SS FF FP	31	176.3±4.6*ab*	170.3±4.7*ab*	96.6±0.9*ab*	3.1±1.0*ab*	1.70±0.60*ab*	1.8±0.4*ab*	1.02±0.23*ab*	0.8±0.2*a*	0.40±0.10*ab*	0.4±0.4*a*	0.25±0.22*a*
SS FF SP	31	177.2±4.6*ab*	172.9±4.7*ab*	97.6±0.9*a*	2.1±1.0*b*	1.14±0.60*b*	1.0±0.4*ab*	0.62±0.23*b*	0.5±0.2*ab*	0.30±0.10*ab*	0.7±0.4*a*	0.37±0.22*a*
SS SF FP	33	182.4±4.4*a*	176.9±4.5*a*	97.1±0.8*a*	2.7±1.0*ab*	1.50±0.60*b*	0.8±0.4*b*	0.50±0.23*b*	0.4±0.2*ab*	0.23±0.09*ab*	1.4±0.4*a*	0.70±0.22*a*
SS SF SP	29	169.9±4.7*ab*	162.8±4.8*bc*	95.9±0.9*ab*	4.1±1.1*ab*	2.36±0.60*ab*	1.6±0.4*ab*	0.89±0.25*ab*	0.2±0.2*b*	0.14±0.10*b*	1.2±0.4*a*	0.69±0.23*a*

a,b Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]Setteble Eggs=normal eggs weighing grester than 52g

[3]Parameters expressed as a percentage of total eggs

*Significant pooled Strain*Feeding Program*Photo Stimulation Program interaction (P<0.05)

Table 4-5. Effects of strain, feeding program and photostimulation program on average weekly egg weights (C-group birds) (Mean ± SEM)

		Age of Birds							
	n[1]	Month 1 27-32 wk	Month 2* 33-36 wk	Month 3 37-40 wk	Month 4 41-44 wk	Month 5 45-48 wk	Month 6 49-52 wk	Month 7* 53-56 wk	Month 8* 57-60 wk
Main Effects									
Strain									
Exp Line (EL)	130	57.0±0.2*a*	61.4±0.2*a*	63.6±0.2*a*	65.3±0.2*a*	66.9±0.2*a*	67.6±0.2*a*	68.3±0.2*a*	68.8±0.2*a*
Shaver Starbro (SS)	124	57.9±0.2*b*	62.5±0.2*b*	64.5±0.2*b*	65.8±0.2*a*	66.8±0.2*a*	67.4±0.2*a*	68.4±0.2*a*	68.4±0.2*a*
Feeding Program									
Fast Feed (FF)	128	57.9±0.2*a*	62.2±0.2*a*	64.4±0.2*a*	65.7±0.2*a*	67.2±0.2*a*	67.7±0.2*a*	68.7±0.2*a*	68.6±0.2*a*
Slow Feed (SF)	126	57.1±0.2*b*	61.6±0.2*b*	63.7±0.2*b*	65.4±0.2*a*	66.3±0.2*b*	67.2±0.2*a*	68.0±0.2*b*	68.7±0.2*a*
Photostim Program									
Fast Photo (FP)	128	57.4±0.2*a*	61.6±0.2*a*	63.9±0.2*a*	65.3±0.2*a*	66.4±0.2*a*	67.2±0.2*a*	68.0±0.2*a*	68.4±0.2*a*
Slow Photo (SP)	126	57.5±0.2*a*	62.2±0.2*b*	64.3±0.2*a*	65.8±0.2*a*	67.1±0.2*b*	67.8±0.2*b*	68.7±0.2*b*	68.9±0.2*a*
Strain*Feeding Program*Photo Stimulation Program									
EL FF FP	32	57.7±0.3*a*	61.8±0.4*bc*	64.1±0.4*ab*	65.6±0.4*abc*	67.3±0.4*ab*	68.1±0.4*a*	68.9±0.5*ab*	69.2±0.5*ab*
EL FF SP	32	57.7±0.3*a*	62.3±0.4*ab*	64.4±0.4*ab*	65.9±0.4*ab*	67.5±0.4*a*	68.0±0.4*a*	69.4±0.4*a*	69.5±0.5*a*
EL SF FP	32	56.1±0.3*b*	60.2±0.4*d*	62.7±0.4*c*	64.6±0.4*c*	65.6±0.4*d*	66.6±0.4*c*	66.8±0.4*c*	68.1±0.4*bc*
EL SF SP	34	56.6±0.3*b*	61.1±0.4*c*	63.4±0.4*bc*	65.1±0.4*bc*	66.3±0.4*bcd*	67.6±0.4*abc*	68.1±0.4*b*	68.4±0.4*abc*
SS FF FP	31	58.2±0 3*a*	62.2±0.4*ab*	64.7±0.4*a*	65.4±0.4*abc*	66.8±0.4*abc*	67.3±0.4*abc*	68.2±0.5*ab*	67.7±0.5*c*
SS FF SP	31	58.1±0.3*a*	62.7±0.4*ab*	64.5±0.4*a*	65.8±0.4*ab*	67.0±0.4*ab*	67.5±0.4*abc*	68.4±0.4*ab*	68.0±0.5*bc*
SS SF FP	33	57.7±0.3*a*	62.3±0.4*ab*	64.0±0.4*ab*	65.5±0.4*abc*	65.8±0.cd	66.8±0.4*bc*	68.1±0.4*b*	68.6±0.4*abc*
SS SF SP	29	57.7±0.3*a*	62.9±0.4*a*	64.8±0.4*a*	66.5±0.4*a*	67.5±0.4*a*	67.9±0.4*ab*	68.9±0.5*ab*	69.6±0.5*a*

a-d Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

*Significant pooled Strain*Feeding Program*Photo Stimulation Program interaction (P<0.05)

Table 4-6. Effects of strain, feeding program and photostimulation program on fertility, hatchability, and incubation traits (C-Group birds) (Mean ± SEM)

					% of eggs set			
	n[1]	Fertility*	Hatchability*	Hatch of Fertile*	Stage 1[2]	Stage 2[3]	Stage 3[4]	Dead in Shell	Cull*
Main Effects									
Strain									
Exp Line (EL)	130	91.18±0.42*a*	83.98±0.50*a*	92.09±0.33*a*	1.88±0.13*a*	1.40±0.11*a*	2.55±0.16*a*	0.30±0.04*a*	1.06±0.15*a*
Shaver Starbro (SS)	124	92.30±0.42*a*	85.44±0.50*a*	92.57±0.33*a*	1.93±0.13*a*	1.50±0.11*a*	2.24±0.16*a*	0.20±0.04*a*	0.99±0.15*a*
Feeding Program									
Fast Feed (FF)	128	91.21±0.42*a*	84.02±0.50*a*	92.09±0.33*a*	1.97±0.13*a*	1.39±0.11*a*	2.39±0.16*a*	0.28±0.04*a*	1.17±0.15*a*
Slow Feed (SF)	126	91.25±0.42*a*	85.40±0.50*a*	92.57±0.33*a*	1.84±0.13*a*	1.51±0.11*a*	2.40±0.16*a*	0.22±0.04*a*	0.88±0.15*a*
Photostim Program									
Fast Photo (FP)	128	91.31±0.42*a*	84.10±0.50*a*	92.08±0.33*a*	1.93±0.13*a*	1.54±0.11*a*	2.58±0.16*a*	0.25±0.04*a*	0.90±0.15*a*
Slow Photo (SP)	126	92.16±0.42*a*	85.32±0.50*a*	92.58±0.33*a*	1.88±0.13*a*	1.36±0.11*a*	2.21±0.16*a*	0.25±0.04*a*	1.15±0.15*a*
Strain*Feeding Program*Photo Stimulation Program									
EL FF FP	32	88.33±0.84*b*	79.89±1.00*b*	90.42±0.66*c*	2.24±0.26*a*	1.51±0.23*a*	3.19±0.32*a*	0.38±0.08*a*	1.11±0.29*ab*
EL FF SP	32	92.60±0.84*a*	84.53±1.00*a*	91.29±0.66*bc*	2.05±0.26*a*	1.39±0.23*a*	2.41±0.32*ab*	0.33±0.08*ab*	1.89±0.29*a*
EL SF FP	32	91.15±0.84*a*	84.74±1.00*a*	92.96±0.66*ab*	1.63±0.26*a*	1.40±0.23*a*	2.34±0.32*ab*	0.31±0.08*ab*	0.72±0.29*b*
EL SF SP	34	92.61±0.84*a*	86.77±1.00*a*	93.71±0.66*a*	1.60±0.26*a*	1.29±0.23*a*	2.27±0.32*b*	0.16±0.08*b*	0.51±0.29*b*
SS FF FP	31	93.11±0.84*a*	86.42±1.00*a*	92.83±0.66*ab*	2.02±0.26*a*	1.54±0.23*a*	2.20±0.32*b*	0.13±0.08*b*	0.80±0.29*b*
SS FF SP	31	90.82±0.84*a*	85.22±1.00*a*	93.84±0.66*a*	1.56±0.26*a*	1.10±0.23*a*	1.78±0.32*b*	0.27±0.08*ab*	0.88±0.29*b*
SS SF FP	33	92.65±0.84*a*	85.34±1.00*a*	92.12±0.66*bc*	1.84±0.26*a*	1.72±0.23*a*	2.60±0.32*ab*	0.17±0.08*ab*	0.98±0.29*b*
SS SF SP	29	92.61±0.84*a*	84.76±1.00*a*	91.49±0.66*bc*	2.30±0.26*a*	1.63±0.23*a*	2.37±0.32*ab*	0.23±0.08*ab*	1.31±0.29*ab*

a-c Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly ($P<0.05$)

[1]n=number of birds in each treatment

[2]Stage 1=mortality occurring during 0-7 d of incubation

[3]Stage 2=mortality occurring during 8-14 d of incubation

[4]Stage 3=mortality occurring after 14 d of incubation

*Significant pooled Strain*Feeding Program*Photo Stimulation Program interaction ($P<0.05$)

Table 4-7. Effects of strain, feeding program and photostimulation program on BW, shank length , liver wt, breast wt, and abdominal fat pad wt at 60 wk of age (C-Group birds) (Mean ± SEM)

					Liver wt		Breast wt		Abdominal fatpad wt	
	n[1]	BW, g	21 wk Shank length, mm	Shank length, mm	g	% BW	g	% BW	g	%BW
Main Effects										
Strain										
Exp Line (EL)	130	3673±30*a*	101.1±0.3*a*	104.4±0.3*a*	51.8±0.9*a*	1.41±0.02*a*	604.0±7.2*a*	16.43±0.13*a*	174.6±5.3*a*	4.69±0.13*a*
Shaver Starbro (SS)	124	3672±31*a*	102.8±0.3*b*	106.1±0.3*b*	53.6±0.9*b*	1.46±0.02*a*	548.7±7.4*b*	14.93±0.13*b*	180.9±5.4*a*	4.88±0.13*a*
Feeding Program										
Fast Feed (FF)	128	3688±30*a*	102.0±0.3*a*	105.6±0.3*a*	51.6±0.9*a*	1.41±0.02*a*	574.2±7.3*a*	15.57±0.13*a*	182.1±5.4*a*	4.88±0.13*a*
Slow Feed (SF)	126	3657±30*a*	102.0±0.3*a*	104.9±0.3*a*	53.7±0.9*b*	1.47±0.02*b*	578.5±7.3*a*	15.79±0.13*a*	173.4±5.4*a*	4.70±0.13*a*
Photostim Program										
Fast Photo (FP)	128	3676±30*a*	101.6±0.3*a*	105.5±0.3*a*	52.1±0.9*a*	1.42±0.02*a*	581.6±7.3*a*	15.82±0.13*a*	173.9±5.4*a*	4.81±0.13*a*
Slow Photo (SP)	126	3669±30*a*	102.4±0.3*a*	105.1±0.3*a*	53.2±0.9*a*	1.45±0.02*a*	571.1±7.3*a*	15.55±0.13*a*	176.2±5.4*a*	4.77±0.13*a*
Strain*Feeding Program*Photo Stimulation Program										
EL FF FP	32	3745±61*a*	100.9±0.6*cd*	105.5±0.6*a*	49.4±1.8*b*	1.32±0.05*a*	620.6±14.6*a*	16.58±0.27*a*	182.3±10.8*a*	4.76±0.25*a*
EL FF SP	32	3667±61*a*	101.5±0.6*cd*	104.8±0.6*ab*	51.8±1.7*ab*	1.41±0.04*ab*	592.2±14.6*abc*	16.13±0.27*a*	171.4±10.8*a*	4.63±0.25*a*
EL SF FP	32	3656±60*a*	100.6±0.6*d*	103.8±0.6*b*	43.2±1.7*ab*	1.46±0.04*a*	608.9±14.4*a*	16.64±0.26*a*	173.6±10.8*a*	4.69±0.25*a*
EL SF SP	34	3623±59*a*	101.5±0.6*bcd*	103.7±0.6*b*	42.7±1.7*ab*	1.46±0.04*a*	594.1±14.2*ab*	16.37±0.26*a*	171.1±10.4*a*	4.70±0.25*a*
SS FF FP	31	3702±61*a*	102.3±0.6*abcd*	106.3±0.6*a*	52.0±1.8*ab*	1.41±0.05*ab*	553.1±14.cd	14.96±0.27*b*	194.6±10.8*a*	5.21±0.25*a*
SS FF SP	31	3637±61*a*	103.3±0.6*a*	105.9±0.6*a*	53.4±1.7*ab*	1.47±0.04*a*	530.7±14.6*d*	14.61±0.27*b*	180.2±10.8*a*	4.90±0.25*a*
SS SF FP	33	3602±61*a*	102.4±0.6*abc*	106.2±0.6*a*	53.9±1.8*ab*	1.50±0.05*a*	543.6±14.6*d*	15.08±0.27*b*	166.7±10.8*a*	4.58±0.25*a*
SS SF SP	29	3748±63*a*	103.2±0.6*ab*	105.9±0.6*a*	55.2±1.8*a*	1.47±0.05*a*	567.5±15.1bcd	15.08±0.28*b*	182.1±11.3*a*	4.84±0.25*a*

a-d Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]Breast wt=wt of *Pectoralis major* and *Pectoralis minor*

Table 4-8. Effects of strain, feeding program and photostimulation program on oviduct wt, ovary wt, stroma wt, # LYF, and # SYF at 60 wk of age (C-Group birds) (Mean ± SEM)

		Oviduct wt		Ovary wt		Stroma wt			
	n[1]	g*	% BW*	g	% BW	g	% BW	#SYF[2]	#LYF[3]
Main Effects									
Strain									
Exp. Line (EL)	130	67.4±1.2*a*	1.85±0.04*a*	42.7±1.2*a*	1.17±0.03*a*	9.5±0.2*a*	0.26±0.01*a*	16.5±0.6*a*	4.3±0.1*a*
Shaver Starbro (SS)	124	66.0±1.2*a*	1.83±0.04*a*	41.6±1.2*a*	1.15±0.03*a*	8.4±0.2*a*	0.28±0.01*b*	14.5±0.6*b*	4.5±0.1*a*
Feeding Program									
Fast Feed (FF)	128	65.3±1.2*a*	1.79±0.04*a*	41.5±1.2*a*	1.14±0.03*a*	8.8±0.2*a*	0.25±0.01*a*	14.7±0.6*a*	4.2±0.1*a*
Slow Feed (SF)	126	68.1±1.2*a*	1.89±0.04*a*	42.7±1.2*a*	1.18±0.03*a*	9.0±0.2*a*	0.25±0.01*a*	16.3±0.6*a*	4.5±0.1*a*
Photostim Program									
Fast Photo (FP)	128	56.4±1.2*a*	1.82±0.04*a*	41.3±1.2*a*	1.14±0.03*a*	8.7±0.2*a*	0.24±0.01*a*	15.8±0.6*a*	4.4±0.1*a*
Slow Photo (SP)	126	67.0±1.2*a*	1.85±0.04*a*	43.0±1.2*a*	1.18±0.03*a*	9.0±0.2*a*	0.25±0.01*a*	15.2±0.6*a*	4.4±0.1*a*
Strain*Feeding Program*Photo Stimulation Program									
EL FF FP	32	54.6±2.4*bc*	1.73±0.08*bc*	39.1±2.4*b*	1.06±0.07*b*	9.3±0.4*abc*	0.25±0.01*abc*	16.0±1.2*ab*	4.0±0.2*c*
EL FF SP	32	70.9±2.4*ab*	1.95±0.08*a*	46.0±2.4*a*	1.26±0.07*a*	9.5±0.4*ab*	0.36±0.01*ab*	15.1±1.2*ab*	4.5±0.2*abc*
EL SF FP	32	68.7±2.4*ab*	1.90±0.08*ab*	43.3±2.4*ab*	2.19±0.07*ab*	9.3±0.4*abc*	0.26±0.01*ab*	17.1±1.2*ab*	4.6±0.2*ab*
EL SF SP	34	65.3±2.3*abc*	1.82±0.08*abc*	42.2±2.3*b*	1.17±0.06*ab*	9.9±0.4*a*	0.27±0.01*a*	18.1±1.2*a*	4.1±0.2*bc*
SS FF FP	31	60.8±2.4*c*	1.67±0.08*c*	38.3±2.4*b*	1.05±0.07*b*	8.2±0.4*d*	0.22±0.01*c*	14.1±1.2*b*	4.0±0.2*bc*
SS FF SP	31	64.8±2.4*abc*	1.81±0.08*abc*	42.8±2.4*ab*	1.19±0.07*ab*	8.4±0.4*bcd*	0.23±0.01*bc*	13.8±1.2*b*	4.5±0.2*abc*
SS SF FP	33	71.4±2.4*a*	2.00±0.08*a*	44.6±2.4*ab*	1.25±0.07*a*	8.7±0.4*bcd*	0.34±0.01*bc*	16.2±1.2*ab*	4.9±0.2*a*
SS SF SP	29	66.9±2.5*abc*	1.83±0.08*abc*	40.8±2.5*ab*	1.10±0.07*ab*	8.3±0.4*cd*	0.32±0.01*c*	14.1±1.2*b*	4.6±0.2*ab*

*a,b,c*Means within a column for each main effect and Strain*Feeding Program*Photo Stimulation Program with no common alphabetic letter differ significantly (P<0.05)

[1]n=number of birds in each treatment

[2]#SYF=number of small yellow follicles (5-10 mm diameter)

[3]#LYF=number of large yellow follicles (>10 mm diameter)

*Significant pooled Strain*Feeding Progrtam*Photo Stimulation Program interaction (P<0.05)

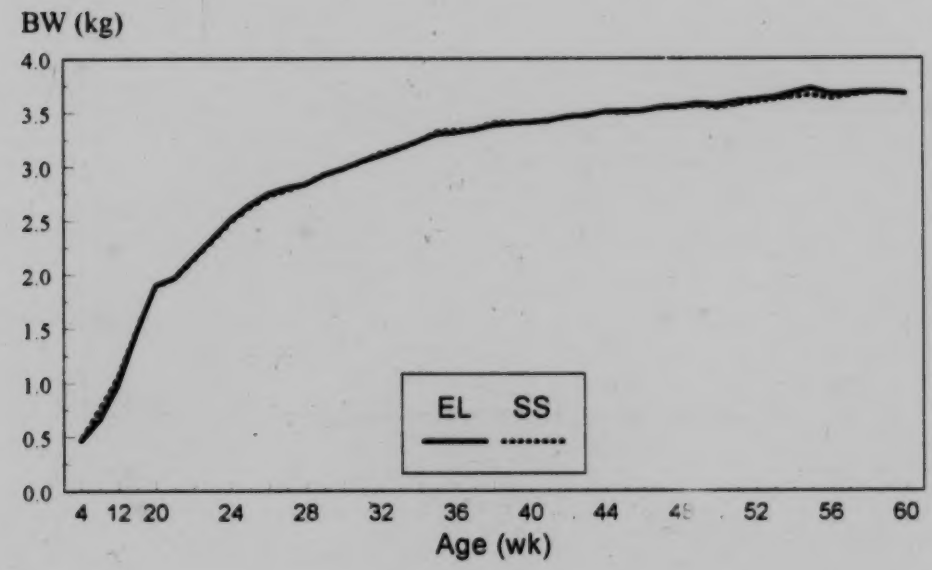

FIGURE 4-1. Weekly body weights of the C-Group birds for the main effect of strain (EL=Experimental Line; SS=Shaver Starbro).

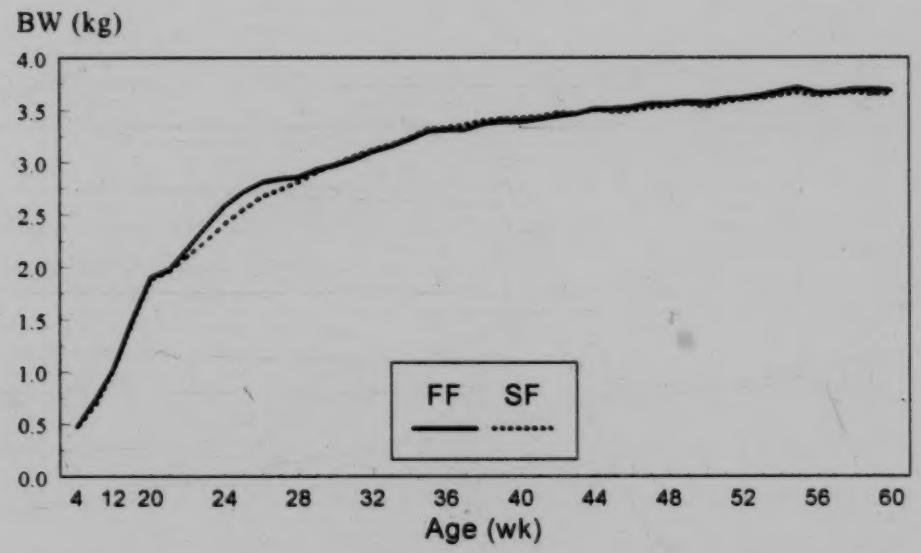

FIGURE 4-2. Weekly body weights of the C-Group birds for the main effect of feeding program (FF=Fast Feed; SF=Slow Feed).

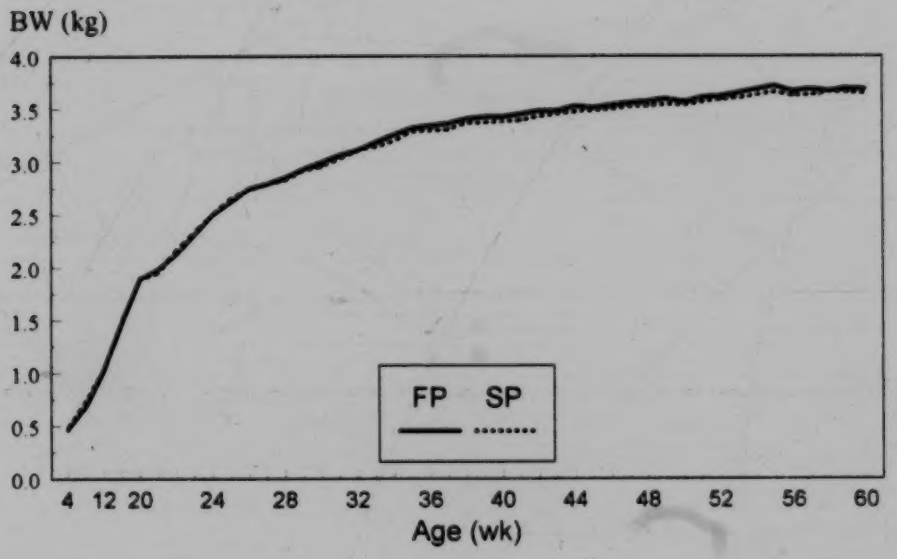

FIGURE 4-3. Weekly body weights of the C-Group birds for the main effect of photostimulation program (FP=Fast Photoperiod, SP=Slow Photoperiod).

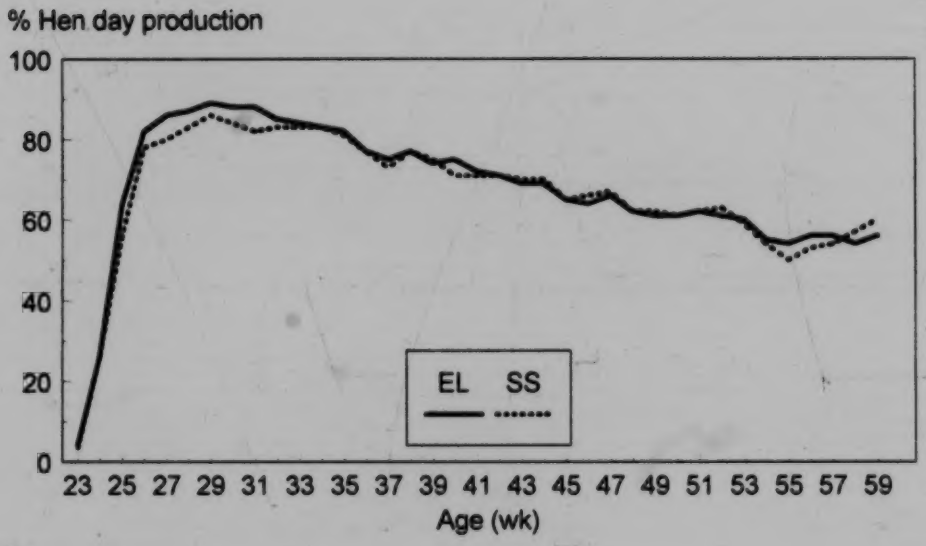

FIGURE 4-4. Weekly hen day egg production for the main effect of strain (EL=Experimental Line, SS=Shaver Starbro).

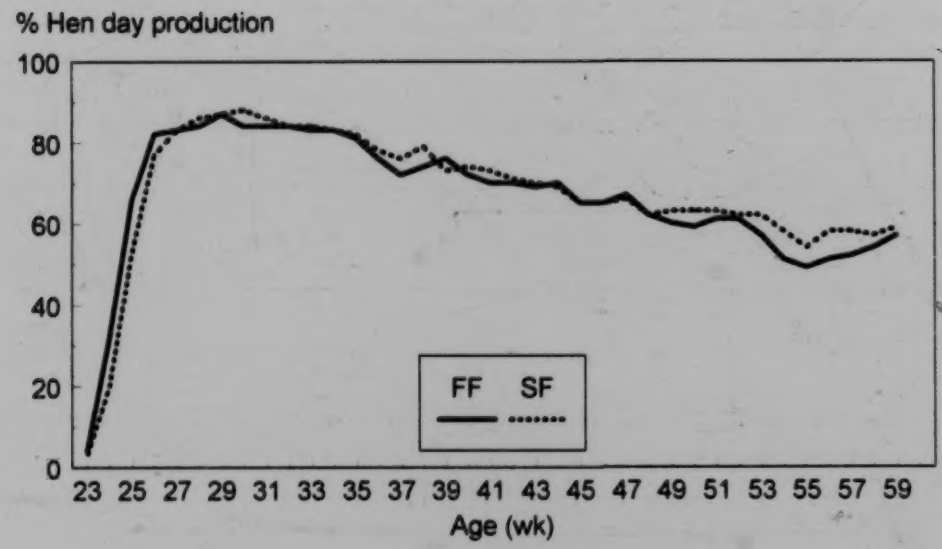

FIGURE 4-5. Weekly hen day egg production for the main effect of feeding program (FF=Fast Feed, SF=Slow Feed)

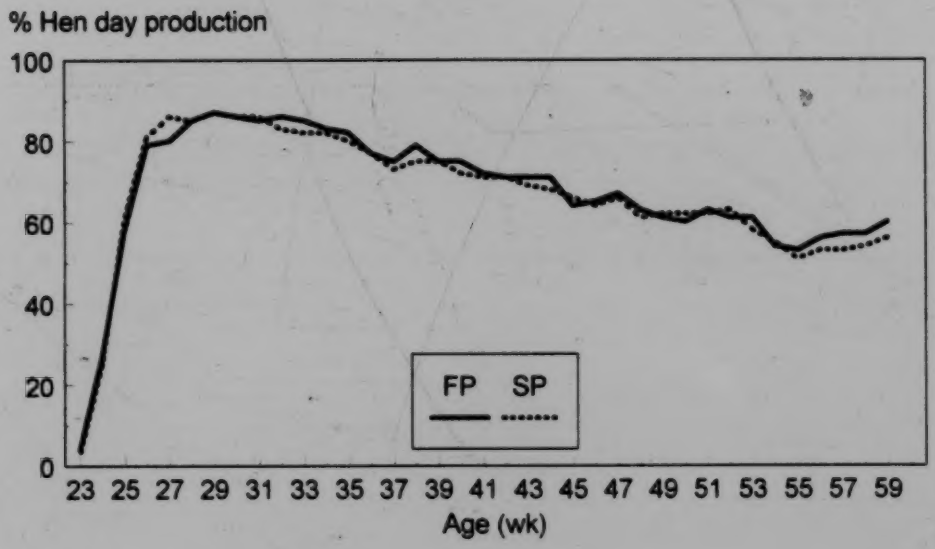

FIGURE 4-6. Weekly hen day egg production for the main effect of photostimulation program (FP=Fast Photoperiod; SP=Slow Photoperiod).

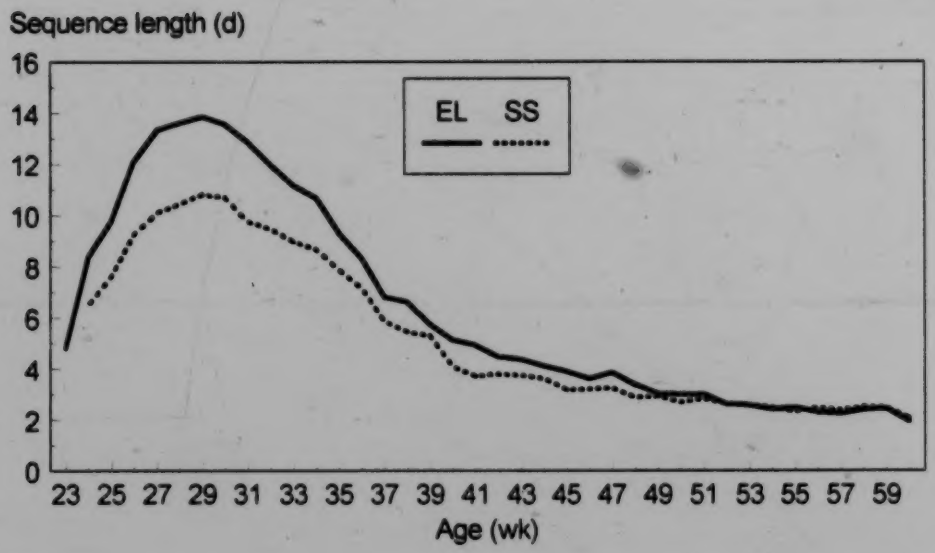

FIGURE 4-7. Weekly sequence length for the main effect of strain (EL=Experimental Line; SS=Shaver Starbro).

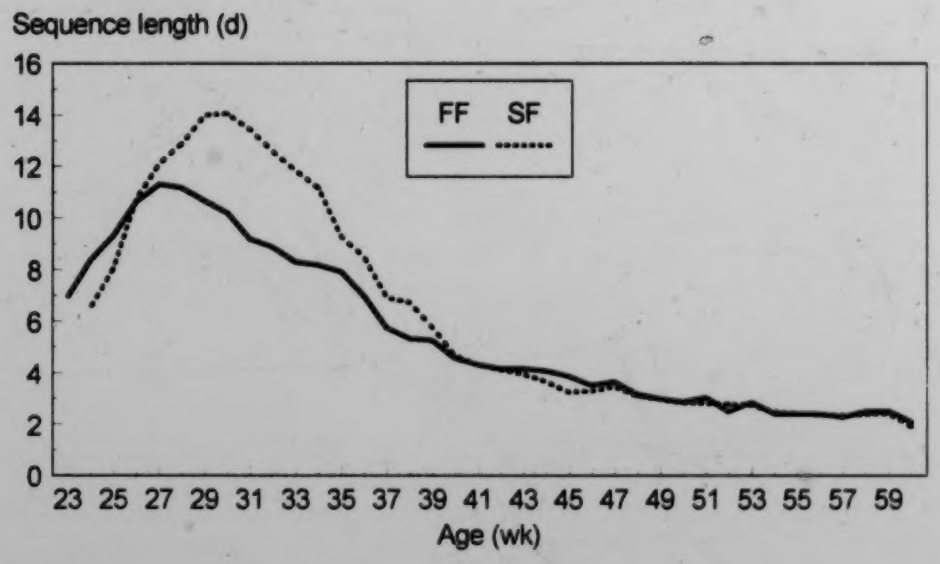

FIGURE 4-8. Weekly sequence length for the main effect of feeding program (FF=Fast Feed, SF=Slow Feed).

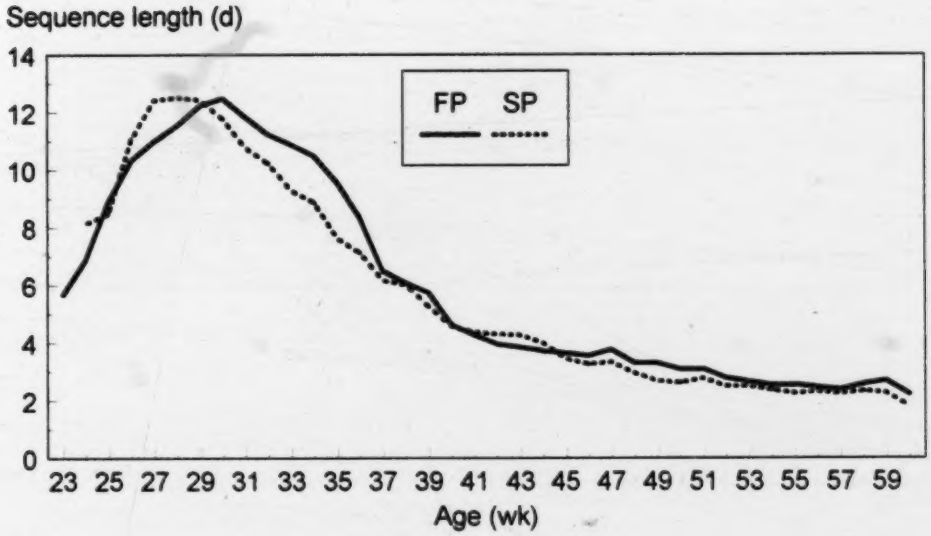

FIGURE 4-9. Weekly sequence length for the main effect of photostimulation program (FP=Fast Photoperiod; SP=Slow Photoperiod).

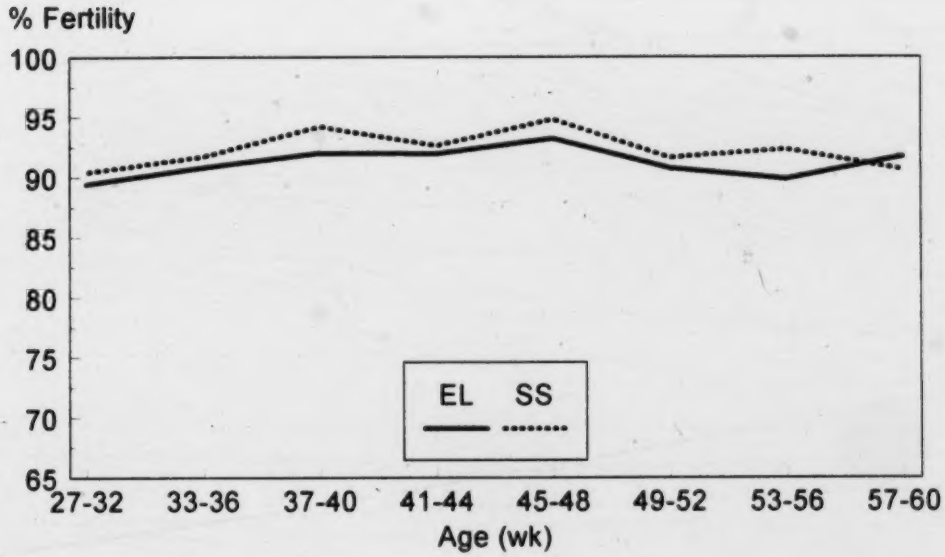

FIGURE 4-10. Monthly percent fertility for the main effect of strain (EL=Experimental Line; SS=Shaver Starbro).

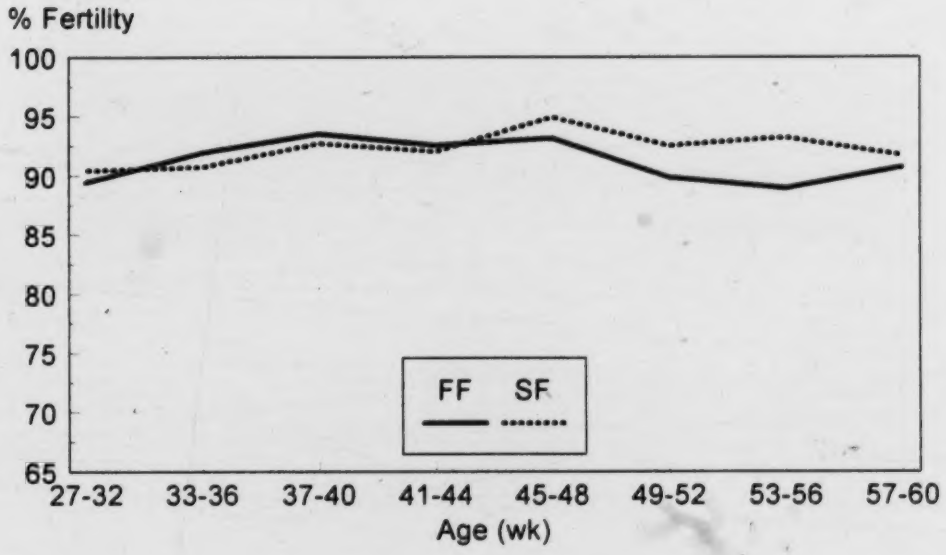

FIGURE 4-11. Monthly percent fertility for the main effect of feeding program (FF=Fast Feed. SF=Slow Feed).

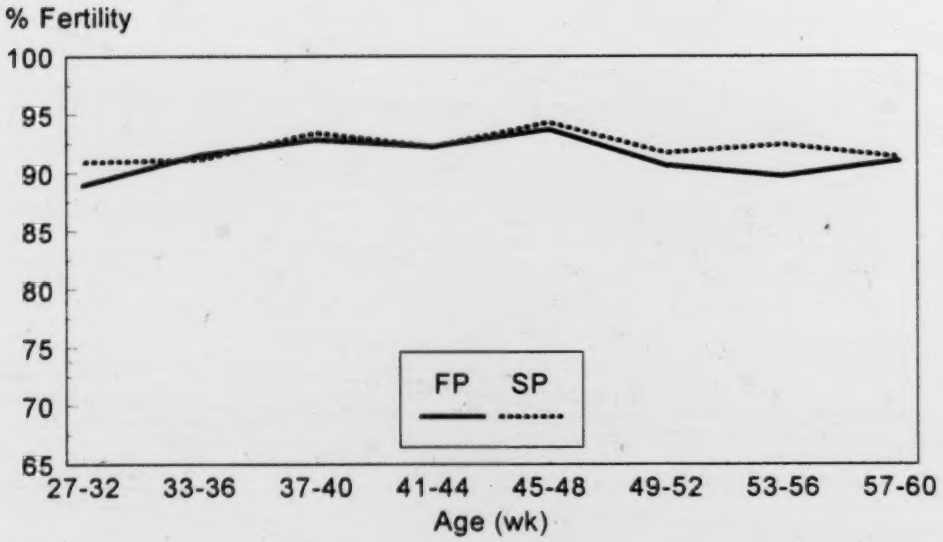

FIGURE 4-12. Monthly percent fertility for the main effect of photostimulation program (FP=Fast Photoperiod, SP=Slow Photoperiod).

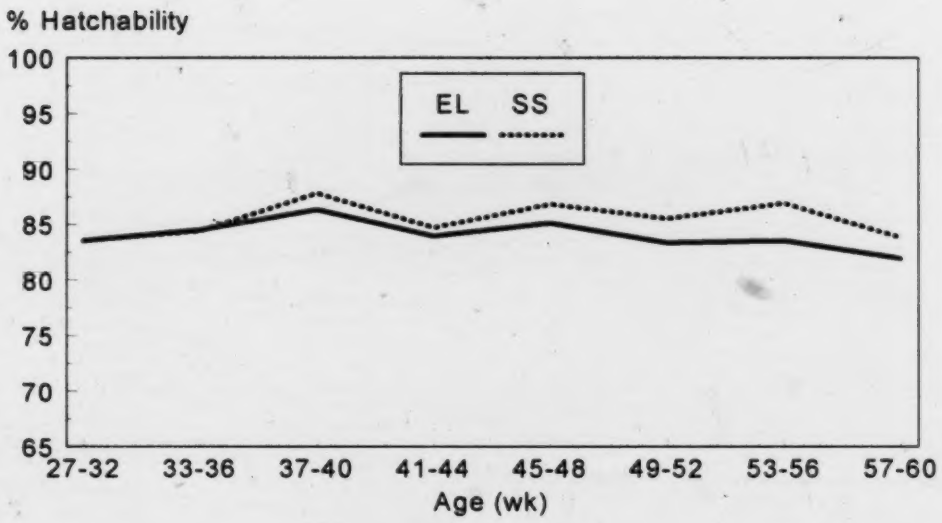

FIGURE 4-13. Monthly percent hatchability for the main effect of strain (EL=Experimental Line; SS=Shaver Starbro).

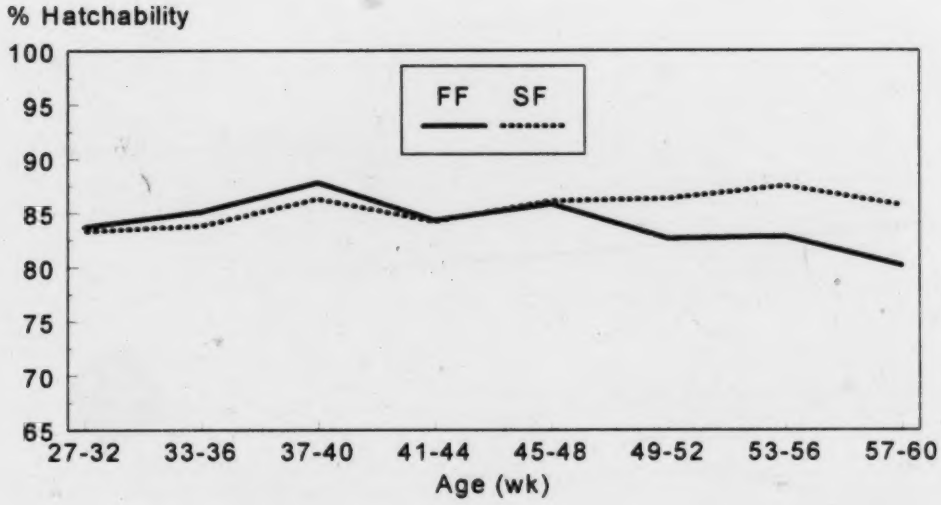

FIGURE 4-14. Monthly percent hatchability for the main effect of feeding program (FF=Fast Feed; SF=Slow Feed).

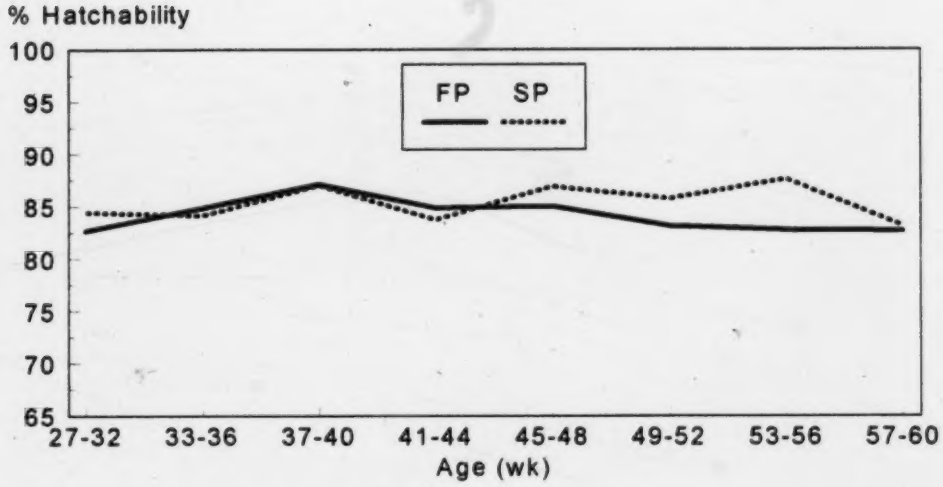

FIGURE 4-15. Monthly percent hatchability for the main effect of photostimulation program (FP=Fast Photoperiod; SP=Slow Photoperiod).

REFERENCES

Bahr, J.M. and Palmer, S.S. 1989. The influence of aging on ovarian function. Crit. Rev. Poult. Biol. **2**:103-110.

Etches, R.J. 1990. The Ovulatory Cycle of the Hen. CRC Crit. Rev. Poult. Biol. **2**: 293-318.

Fatorri, T.R., Wilson, H.R., Harms, R.H., and Miles, R.D. 1991. Response of broiler breeder females to feed restriction below recommended levels. 1. Growth and reproductive performance. Poult. Sci. **70**. 26-36.

Goerzen, P.R. 1996. Effects of body weight and age at photostimulation on reproductive efficiency in meat-type hens (*Gallus domesticus*). M.Sc. Thesis. University of Alberta, Edmonton, AB.

Hocking, P.M., Gilbert, A.B., Walker, M., and Waddington, D. 1987. Ovarian follicular structure of White Leghorn fed *ad libitum* and Dwarf and normal broiler breeders fed *ad libitum* or restricted to point of lay. Br. Poult. Sci. **28**: 493-506.

Hocking, P.M., Waddington, D., Walker, M.A., and Gilbert, A.B. 1989. Control of the development of the ovarian follicular hierarchy of broiler breeder pullets. Br. Poult. Sci. **34**: 793-801.

Jaap, R.G. and Muir, F.V. 1968. Erratic oviposition and egg defects in broiler-type pullets. Poult. Sci. **47**: 417-423.

Johnson, P.A., Dickerman, R.W., and Bahr, J.M. 1986. Decreased granulosa cell luteinizing hormone sensitivity and altered thecal estrdial concentration in the aged hen (*Gallus domesticus*). Biol. Reprod. **35**: 641-646.

Katanbaf, M.N., Dunnington, E.A., and Siegel, P.B. 1989. Restricted feeding in early and late-feathering chickens. 2. Reproductive responses. Poult. Sci. **68**: 353-358.

Lupicki, M. 1994. Ovarian morphology and steroidogenesis in domestic fowl (*Gallus domesticus*). Effects of aging, strain, photostimulation program, and level of feeding. M.Sc. Thesis. University of Alberta, Edmonton, AB.

O'Sullivan, N.P., Dunnington, E.A., and Siegel, P.B. 1991. Relationships among age of dam, egg components, embryo lipid transfer, and hatchability of broiler breeder eggs. Poult. Sci. **70**: 2180-2185.

Robinson, F.E., Hardin, R.T., and Robblee, A.R. 1990. Reproductive senescence in domestic fowl: Effects on egg production, sequence length and inter-sequrnce pause length. Br. Poult. Sci. **31**: 871-879.

Robinson, F.E., Wilson, J.L., Yu, M.W., Fasenko, G.M., and Hardin, R.T. 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. **72**: 912-922.

Robinson, F.E., Lupicki, M.E., Wautier, T.A., Robinson, N.A., Hardin, R.T., and Wilson, J.L. 1995a. Feed and photoperiod management of broiler breeder hens: limiting ovarian development to maximize chick production. Pages 196-205 *in*: Proceedings of the 16th Western Nutrition Conference. September 13/14, 1995, Saskatoon, Saskatchewan.

Robinson, F.E., Robinson, N.A., Hardin, R.T., and Wilson, J.L. 1995b. The effects of 20-week body weight and feed allocation during early lay on female broiler breeders. J. Appl. Poultry Res **4**: 203-210.

Sas Institute. 1994. The SAS System for Windows 3.10, Release 6.10. Cary, NC, USA 27513.

Steel, R.G.D., and Torrie, J.H. 1980. Principles and Procedures of Statistics. 2nd edition. McGraw-Hill Book Co. Inc., New York, NY.

Summers, J.D. and Leeson, S. 1985. Poultry Nutrition Handbook. University of Guelph, Guelph, ON, Canada.

Van Middelkoop, J.H. 1971. Shell abnormalities due to the presence of two eggs in the shell gland. Archiv fur Geflugelkunde **35**: 122-127.

Van Middelkoop, J.H. 1972. The relationship between ovulation interval of White Plymouth Rock pullets and the laying of abnormal eggs. Archiv fur Geflugelkunde **36**: 223-230.

Waddington, D., Perry, M.M., Gilbert, A.B., and Hardie, M.A. 1985. Follicular growth and atresia in the ovaries of hens (*Gallus domesticus*) with diminished egg production rates. J. Reprod. Fertil. **74**: 399-405.

Williams, J.B. and Sharp, P.J. 1978a. Ovarian morphology and rates of ovarian follicular development in laying broiler breeders and commercial egg producing hens. Br. Poultry Sci. **19**: 387-395.

Williams, J.B. and Sharp, P.J. 1978b. Age-dependent changes in the hypothalamo-pituitary-ovarian axis of the laying hen. J. Reprod. Fertil. **53**: 141-146.

Wilson, J.L, Robinson, F.E., Robinson, N.A., and Hardin, R.T. 1995. Effects of feed allocation on female broiler breeders. J. Appl. Poultry Res. **4**: 193-202.

Yu, M.W., Robinson, F.E., Charles, R.G. and Weingardt, R. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders. 2. Ovarian morphology and production. Poult. Sci. **71**: 1750-1761.

Yu, M.W., Robinson, F.E., and Etches, R. J. 1992c. Effect of feed allowance during rearing and breeding on female broiler breeders. 3. Ovarian steroidogenesis. Poult. Sci. **71**: 1762-1767.

Yu, M.W., Robinson, F.E., and Robblee, A.R. 1992a. Effect of feed allowance during rearing and breeding on female broiler breeders. 1. Growth and carcass characteristics. Poult. Sci. **71**:1739-1749.

5. GENERAL DISCUSSION

5.1 INTRODUCTION

"We want broiler breeders to think and act like leghorns but we want their offspring to show that they are broilers" (Robinson and Wilson, 1996). Compared with egg-type chickens, broiler breeders lay approximately half as many eggs (Hocking *et al*, 1987, 1989). In the past, geneticists have been concerned with improving reproductive efficiency of conventional broiler breeders. Now that the public is becoming more health conscious, geneticists are continually faced with the task of improving high breast yield strains that carry more breast muscle than conventional strains. However, a problem arises in that muscle growth and reproductive efficiency are negatively correlated. Selection for improved growth and carcass characteristics in progeny has a negative effect on the reproductive potential of the parent stock (Siegel and Dunnington, 1985). Feed restriction is routinely used with broiler breeders to control BW in order to keep reproductive problems to a minimum. It has been reported (Robinson *et al*, 1991; Yu *et al*, 1992a, 1992b; Robinson *et al*, 1993) that restricting feed during the prebreeding and breeding period increases reproductive performance of broiler breeders. What is not known is the effects of small differences in feed allocation early in lay.

This research had two prime objectives. The first objective was to determine the effects of increasing day length and light intensity on the attainment of sexual maturity in broiler breeder pullets. The second objective was to determine the effects of strain, feeding program, and photo stimulation program on ovarian morphology and carcass traits at photo stimulation, sexual maturity, and at the end of lay. As well, reproductive efficiency as a result of strain, feeding program, and photo stimulation program were of interest, in terms of total and settable egg production and fertility and hatchability. It was of interest to attempt to repeat some results of an experiment by Robinson *et al* (1995) in which two different feeding programs and two different photo stimulation programs were implemented.

5.2 GENERAL DISCUSSION

Much of the work dealing with light intensity has been conducted with turkeys. There is very little

data published on the effects of light intensity in terms of ovarian morphology at sexual maturity in broiler breeder pullets. Chapter 2 dealt with the effects of increasing day length and light intensity alone and in combination on attainment of sexual maturity in broiler breeder pullets. Effects of light intensity on sexual maturity are not clear, but it is clear that increasing day length has an effect on the attainment of sexual maturity in poultry. Although birds maintained on short days (8L:16D) will eventually reach sexual maturity, it occurs far sooner in birds that are photo stimulated (eg. 15L:9D). Sexual maturity was delayed by 13 d in birds that were not photo stimulated. Lupicki (1994) reported similar results in that non photo stimulated broiler breeders reached sexual maturity 20 d later than photo stimulated birds. Light intensity had no effect on any trait measured. From the results, it could be implied that a light intensity of 10 lux is adequate for normal sexual development in this strain of broiler breeder. More research needs to be conducted to determine if there is a threshold light intensity after which no further effects could be measured.

It has been stated on numerous occasions that those strains selected for high breast yield are not as reproductively efficient as conventional strains. Not much documentation exists on the effects of feed restriction on the onset of sexual maturity, carcass traits, and ovarian morphology, but there has been little work on the effects of minor differences in feed allocation and its influence on ovarian form and function. Chapters 3 and 4 looked at how strain, feeding program, and photo stimulation program affect ovarian morphology, carcass traits, and reproductive efficiency at photo stimulation, sexual maturity, and at the end of lay.

The effect of minor differences in feed allocation as well as photo stimulation programs differing in the amount of light received each week have been investigated by Robinson *et al* (1995). It was found that a slow feeding program resulted in more total eggs, which was a result that we wanted to attempt to repeat. Until now, these main effects along with different strains have not been examined.

It was observed that the conventional breed had a longer shank length than the experimental line, indicating a larger frame size. This was not surprising as birds selected for high breast yield would normally have a smaller frame size. As was expected, the EL birds had a greater breast muscle wt. This was observed at photo stimulation, sexual maturity, and at the end of lay. Although EL birds had a lighter BW at sexual maturity, breast wt was greater as an absolute basis as well as a % of BW. It has been postulated and reported

that birds require minimum requirements of age (Brody, 1980), BW (Bornstein *et al*, 1984; Soller *et al*, 1984), lean body mass and carcass fat (Soller *et al*, 1984) in order to attain sexual maturity. At sexual maturity, it was observed that the values for carcass protein and carcass fat were quite constant supporting results that a minimum requirement for lean body mass and carcass fat exist.

The EL birds laid relatively the same amount of total and settable eggs as the SS birds, and had a longer prime sequence length, concluding that in this experiment, the conventional strain was not reproductively superior to the strain more highly selected for breast muscle yield. Both strains were managed according to BW targets and feed allocation for the commercial strain; possibly, more attention needs to be paid to management of the high breast yield strains. As this project only dealt with two strains from one breeding company, further research needs to be conducted with different strains, both conventional and high breast yield, from other breeders. Also, it may be of some use to look at different BW curves, not to just select birds that are closest to target BW, as producers do not have this luxury. Using birds that are excessively light or heavy, as well as the intermediate weight would prove to be more useful from an industrial standpoint. While feeding program did not have an effect on the number of LYF at sexual maturity or at the end of lay, it appears that slow fed birds had a better control over the ovary in terms of follicular recruitment and maturation as these birds had longer prime sequence lengths as well as better total and settable egg production than the fast fed birds. A higher incidence of double-yolked eggs were observed in birds fed more aggressively during the early laying period; this is another reason why total and settable egg production would have been lower in these birds. Similar results for egg production were reported by Robinson *et al* (1995). From these results, it can be concluded that a slow feeding program is better in that more eggs are produced. It may be useful to also look at the effects of small differences in feed allocation at peak production and just after peak production to improve persistency of lay. The product of the parent breeder operation is the fertile hatching egg, so careful attention needs to be paid in maximizing egg output, specifically fertile egg output. Photo stimulation program had very few effects on any traits measured.

From these results, it appears that following recommended breeder guidelines is important, but there is a possibility that target BW should be changed for strains as the strain selected for breast yield was managed as the conventional breed and still had equally as good production records as the conventional

strain. Careful attention needs to be paid to feeding strategies at particular stages of egg production. It was obvious from these trials that small differences in feed allocation at early lay have an effect on ovarian morphology.

5.3 CONCLUSIONS

Increasing day length seems to be one of the most important management factors in terms of achieving sexual maturity at an earlier age. It is still unclear the role that light intensity plays in the attainment of sexual maturity. These results have shown that there is no difference between 10 and 100 lux, but it is not known if a threshold intensity exists. It seems that 10 lux of light intensity is sufficient for normal sexual development. Contrary to popular belief, the commercial strain was not found to be reproductively superior to the strain that was more highly selected for breast yield. This belief is most likely due to the fact that when there is selection for improved growth characteristics, reproductive efficiency suffers. This was not the case in this experiment. It appears that superior egg production is a result, partly, of management. Both strains were managed as the commercial strain, for BW targets and weekly feed allocation, and both strains were quite equal in their production characteristics. It was also shown that a more conservative approach to feed restriction early in lay is more beneficial than an aggressive approach. This feeding program is beneficial in that it reduced the incidence of multiple-yolked eggs while improving prime sequence length and persistency of lay. Close attention needs to be paid to follicular growth and recruitment and how these are affected by different management techniques such as feed restriction.

5.4 REFERENCES

Bornstein, S., Plavnik, I., and Lev, Y. 1984. Body weight and/or fatness as potential determinants of the onset of egg production in broiler breeder hens. Br. Poult. Sci. **25**: 323-341.

Brody, T., Eitan, Y., Soller, M., Nir, I., And Nitsan, Z. 1980. Compensatory growth and sexual maturity in broiler females reared under severe food restriction from day of hatching. Br. Poult. Sc. **21**: 437-446.

Hocking, P.M., Gilbert, A.B., Walker, M., and Waddington, D. 1987. Ovarian follicular structure of White Leghorn fed *ad libitum* and Dwarf and normal broiler breeders fed *ad libitum* or restricted to point of lay. Br. Poult. Sci. **28**: 493-506.

Hocking. P.M., Waddington, D., Walker, M.A., and Gilbert, A.B. 1989. Control of the development of the ovarian follicular hierarchy in broiler breeder pullets by food restriction during rearing. Br. Poult. Sci. **28:** 495-506.

Lupicki, M. 1994. Ovarian morphology and steroidogenesis in domestic fowl (*Gallus domesticus*): Effects of aging, strain, photostimulation program, and level of feeding. M.Sc. Thesis. University of Alberta, Edmonton, AB.

Robinson, F.E., Robinson, N.A., and Scott, T.A. 1991. Reproductive performance, growth rate, and body composition of full-fed versus feed-restricted broiler hens. Can. J. Anim. Sci. **71**: 549-556.

Robinson, F.E., Wilson, J.L., Yu, M.W., Fasenko, G.M., and Hardin, R.T. 1993. The relationship between body weight and reproductive efficiency in meat-type chickens. Poult. Sci. **72**: 912-922.

Robinson, F.E., Lupicki, M.E., Wautier, T.A., Robinson, N.A., Hardin, R.T., and Wilson, J.L. 1995. Feed and photoperiod management of broiler breeder hens: limiting ovarian development to maximize chick production. Pages 196-205 *in*: Proceedings of the 16th Western Nutrition Conference. September 13.14, 1995, Saskatoon, Saskatchewan.

Robinson, F.E. and Wilson, J.L. 1996. Reproductive failure in overweight male and female broiler breeders. Animal Feed Science Technology **58**: 143-150.

Siegel, P.B. and Dunnington, E.A. 1985. Reproductive complications assoviated with selection for broiler growth. Pages 59-71 *in:* Poultry Genetics and Breeding. W.G. Hill, J.M Manson, and D. Hewitt, ed. British Poultry Science Ltd., Edinburgh, Scotland.

Soller, M., Eitan, Y., and Brody, L. 1984. Effect of diet and early quantitative feed restriction on the minimum weight requirement for onset of sexual maturity in White Rock broiler breeders. Poult. Sci. **63**: 1255-1261.

Yu, M.W., Robinson, F.E., and Robblee, A.R. 1992a. Effect of feed allowance during rearing and breeding on female broiler breeders. 1. Growth and carcass characteristics. Poult. Sci. 71:1739-1749.

Yu, M.W., Robinson, F.E., Charles, R.G. and Weingardt, R. 1992b. Effect of feed allowance during rearing and breeding on female broiler breeders. 2. Ovarian morphology and production. Poult. Sci. 71. 1750-1761.